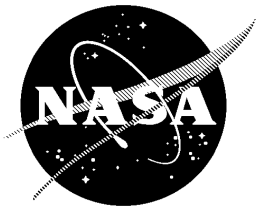
510-4SDS/0196
CSC 10034686

MISSION OPERATIONS AND DATA SYSTEMS DIRECTORATE

Earth Science Data and Information System (ESDIS) Level 1 Product Generation System (LPGS) System Design Specification

March 1997



Goddard Space Flight Center
Greenbelt, Maryland

Earth Science Data and Information System (ESDIS)
Level 1 Product Generation System (LPGS)
System Design Specification

March 1997

Prepared Under Contract NAS5-31000/HQ001057
By Computer Sciences Corporation
CSC 10034686

Prepared by:

Angela A. Bernard 3/19/97

A. Bernard Date
LPGS Systems Engineer, CNMOS
CSC

Approved by:

Robert Schweiss for 3/19/97

J. Henegar Date
LPGS Project Manager
GSFC, Code 514

Reviewed by:

Kathyann Jeletic 3/19/97

K. Jeletic Date
LPGS Systems Engineer
GSFC, Code 511

James D. Pizzola 3/19/97

J. Pizzola Date
LPGS Project Leader, CNMOS
CSC

Concurred by:

Ludie Kidd 3/27/97

L. Kidd Date
Landsat 7 Ground System
Implementation Manager
GSFC, Code 510.1

D. J. DeVito 3/31/97

D. DeVito Date
ESDIS System Engineer
GSFC, Code 505

Goddard Space Flight Center
Greenbelt, Maryland

Preface

The system design specification contains the highest level design information for the Landsat 7 Earth Science Data and Information System (ESDIS) Level 1 Product Generation System (LPGS). The LPGS system design is based on an analysis of the requirements contained in the LPGS functional and performance requirements specification (F&PRS) and the LPGS operations concept and on results from various technical analysis and trade-off studies performed by the LPGS project. The baselined LPGS system design specification is controlled by the LPGS Project Configuration Management Board (PCMB). This document will then be maintained and updated, as required, by the LPGS Project, with updates and revisions approved by the PCMB.

This system design specification was prepared by

Earth Science Data and Information System (ESDIS)
Level 1 Product Generation System (LPGS)
Code 510
Goddard Space Flight Center
Greenbelt, MD 20771

GSFC	cNMOS
[TBD]	[TBD]
[TBD]	[TBD]

Abstract

The Earth Science Data and Information System (ESDIS) Level 1 Product Generation System (LPGS) will be operated within the Earth Observing System (EOS) Ground System (EGS) to provide Landsat 7 Enhanced Thematic Mapper Plus (ETM+) systematically corrected digital images for distribution to EOS Data and Information System (EOSDIS) Core System (ECS) customers. The system design presented in this document is based on the requirements contained in the LPGS functional and performance requirements specification (F&PRS) and the LPGS operations concept document.

***Keywords**: EGS, ESDIS, Landsat, Landsat 7, Level 1 Product Generation System (LPGS)*

Change Information Page

List of Effective Pages	
Page Number	**Issue**
Title page	Original
iii through xvi	Original
1-1 through 1-4	Original
2-1 through 2-19	Original
3-1 through 3-18	Original
4-1 through 4-4	Original
5-1 through 5-6	Original
A-1 through A-8	Original
B-1 through B-8	Original
C-1 through C-3	Original
AB-1 through AB-4	Original
GL-1 through GL-3	Original

Document History			
Document Number	**Status/Issue**	**Publication Date**	**CCR Number**
510-4SDS/0196 CSC 10034686	Original	March 1997	NA

Contents

Section 3. System Design

Section 4. System Support Software

Section 5. Operations Design

Figures

Tables

Section 1. Introduction

1.1 Purpose and Scope

This document establishes the system design for the Earth Science Data and Information System (ESDIS) Level 1 Product Generation System (LPGS). The LPGS system design is based on an analysis of the requirements contained in the LPGS functional and performance requirements specification (F&PRS) and the operations concept, as well as on various technical studies completed by the LPGS Project.

1.2 Goals and Objectives

The LPGS system design goals are to

- Provide Level 1R (L1R) and Level 1G (L1G) processing in support of the Earth Observing System (EOS) Ground System (EGS)
- Maintain system and operations cost and development schedule objectives
- Reduce risks
- Employ Level 1 (L1) processing algorithms common to both the Image Assessment System (IAS) and the LPGS
- Maximize throughput and provide flexibility for expansion

1.3 System Description

A baselined overview of the LPGS system description can be found in the LPGS operations concept (Applicable Document 1).

1.4 Definitions

As defined in this section, several terms are commonly used throughout this document to describe the LPGS operations concept. These terms include the following:

- Level 0R (L0R) digital image—Reformatted, unrectified subinterval
- Level 0R (L0R) product—Level 0R product, distributed by the EOS Data and Information System (EOSDIS) Core System (ECS), includes for all requested bands the following: 0R image data, metadata, internal calibrator (IC) data, calibration parameter file (CPF), the payload correction data (PCD), and the mirror scan correction data (MSCD)
- Level 1R (L1R) digital image—Radiometrically corrected, but not geometrically resampled
- Level 1R (L1R) product—L1 product, packaged by LPGS and distributed by the ECS to the customer, includes for all requested bands the following: L1R image data, metadata

- including processing quality information, IC data file, CPF, combined PCD file, combined MSCD file, and geolocation table in hierarchical data format (HDF).
- Level 1G (L1G) digital image—Radiometrically corrected and resampled for geometric correction and registration to geographic map projections
- Level 1G (L1G) product—L1 product, packaged by LPGS and distributed by the ECS to the customer, includes for all requested bands the following: FAST or GeoTIFF format L1G image and associated data accommodated by the format; HDF-EOS unencapsulated format L1G image, metadata, and CPF
- Production quality assessment (QA)—Ancillary information collected and generated during L1 processing; provides information on the certainty with which corrections were made to images; nominally included in L1 product metadata
- Interval—The time duration between the start and stop of an imaging operation (observation) of the Landsat 7 Enhanced Thematic Mapper Plus (ETM+) instrument
- Subinterval—Segment of time corresponding to a portion of an observation within a single Landsat 7 contact period
- World-wide Reference System (WRS) scene—Digital image that covers an area equivalent to one of the 57,784 scene-centers (233 paths x 248 rows areas) defined by the WRS structure

1.5 Documentation

The documents listed in the subsections that follow contain details regarding the LPGS and external systems.

1.5.1 Applicable Documents

The following documents were used in developing the LPGS system design:

1. National Aeronautics and Space Administration (NASA), Goddard Space Flight Center (GSFC)/Mission Operations and Data Systems Directorate (MO&DSD), 510-3OCD/ 0296, *Level 1 Product Generation System (LPGS) Operations Concept*, February 1997
2. --, 510-FPD/0196, *Earth Science Data and Information System (ESDIS) Level 1 Product Generation System (LPGS) Functional and Performance Requirements Specification*, February 1997
3. NASA, GSFC, *Earth Science Data and Information System (ESDIS) Mission-Specific Requirements for the Landsat 7 Mission L1 Processing*, January 1997
4. --, *Landsat 7 L1 Product Generation System (LPGS) Project Management Plan*, Draft, May 1996
5. --, *Landsat 7 IAS System Design Specification*, December 1996
6. --, *Interface Control Document Between the Level 1 Product Generation System and the Image Analysis System (IAS), Draft*, January 1997
7. --, 560-SDS/0194, *Landsat 7 Processing System (LPS) System Design Specification*, May 1995
8. --, *ESDIS Security Policy and Guidelines*, March 1996
9. --. NHB 2410.9A, *NASA Automated Information Security Handbook*, June 1993

1.5.2 Reference Documents

The following documents contain additional details regarding the LPGS, the ESDIS and Landsat 7 systems and projects, and external systems:

1. NASA, GSFC, 560-3OCD/0194, *Landsat 7 Processing System (LPS) Operations Concept, Revision 2*, April 1996
2. --, *Landsat 7 Detailed Mission Requirements*, May 1995
3. --, *IAS Operations Concept*, December 1994
4. --, 430-15-01-001-0, *Landsat 7 Image Assessment System (IAS) Element Specification, Baseline*, October 1996
5. --, 514-1ICD/0195, *ICD Between IAS and LPS*, January 1996
6. --, 209-CD-013-003, *Interface Control Document (ICD) Between ECS and the Landsat 7 System*, August 1996
7. --, *IRD Between ECS and the Landsat 7 System*
8. --, 505-41-18, *IRD Between EOSDIS and MITI ASTER GDS Project*, July 1995
9. --, 505-41-13, *IRD Between EOSDIS and the Landsat 7 System*, July 1995
10. EOSDIS Core System Project, 223-CD-001-002, *ECS External Data Traffic Requirements*, August 1996
11. --, 604-CD-003-002, *ECS Operations Concept for the ECS Project Part 2A - ECS Release A*, November 1995
12. --, 604-CD-002-003, *ECS Operations Concept for the ECS Project: Part 2B - ECS Release B*, March 1996
13. --, 305-CD-027-002, *Release B SDPS Data Processing Subsystem Design Specification*, March 1996
14. --, 305-CD-029-002, *Release B CSMS System Management Subsystem Design Specification for the ECS Project*, July 1994
15. --, 194-207-SE1-001, *System Design Specification for the ECS Project*, June 1994
16. --, 305-CD-024-002, *Release B SDPS Data Server Subsystem Design Specification for the ECS Project*
17. NASA, GSFC, *Landsat 7 System and Operations Concept*, October 1994
18. NASA, GSFC/MO&DSD, *Mission Operations Concept for the Landsat 7 Ground System*, Draft, June 1995
19. United States Geological Survey (USGS)/National Oceanic and Atmospheric Administration (NOAA), *Index to Landsat Worldwide Reference System (WRS) Landsats 1, 2, 3, and 4*, 1982
20. Computer Sciences Corporation, *SEAS System Development Methodology, SSDM Standards and Procedures, Release 8, October 1994*
21. --, Landsat 7 IAS Interface Definition Document, Draft, December 1996

Section 2. System Design Overview

This section provides an overview of the LPGS system design. It discusses the various design drivers, underlying assumptions, and constraints that significantly affect the system, operational, hardware, and software aspects of the LPGS system design. This section also describes the LPGS system design approach and includes a list of open issues that have a potential impact on LPGS system design.

2.1 LPGS Design Drivers

An *LPGS design driver* is defined as a key system requirement that significantly affects the LPGS system architecture, hardware and software design, and/or the operational approach. Changing such a requirement is expected to have a noticeable impact on some aspects of the LPGS system design. The following are the LPGS design drivers:

Algorithm Driver

- The LPGS must employ the L1 processing algorithms being used by the IAS.

System-Level Drivers

- The LPGS must nominally generate L1 products on a first-ordered, first-processed basis.
- The LPGS must provide the capability to rearrange L1 product processing requests according to operator specification.
- The LPGS must provide the capability to support attended operations 24 hours per day, 7 days per week, on a continuous basis.
- The LPGS must provide the capability to support unattended operations 16 hours per day, 7 days per week, on a continuous basis.
- The LPGS must provide the capability to execute diagnostic tests for verifying proper operation of system capabilities and components.
- The LPGS design must be scaleable to allow for future growth in processing capability.

External Interfaces Drivers

- The LPGS must interface with the EOS Data and Information System (EOSDIS) Core System (ECS) to receive product requests and associated data as well as to transfer the L1 products and associated data.
- The LPGS must interface with the IAS to provide L1 characterization results.
- The LPGS must interface with the Data Handling Management Facility (DHF) to provide L1 processing anomaly reports.

Functional Drivers

- The LPGS must be able to extract and process Landsat 7 ETM+ Earth image data from the L0R product to produce radiometrically corrected L1R digital images and/or systematically corrected L1G digital images.
- The LPGS must provide the capability to sample L1R digital images and apply map projections, as specified in Applicable Document 2.
- The LPGS must provide the capability to detect, characterize, and correct image artifacts, as specified in Applicable Document 2.
- The LPGS must provide the capability to support compensation resampling methods, as specified in Applicable Document 2.
- The LPGS must provide the capability to produce L1G digital images with grid cell characteristics, as specified in Applicable Document 2.
- The LPGS must provide the capability to produce L1G data products that are spatially continuous between contiguous partial subintervals or WRS scenes.
- The LPGS must provide the capability to generate L1G data products oriented to a nominal path or to North-up.
- The LPGS must package and deliver performance and quality data with each L1R and L1G product, as specified in Applicable Document 2.
- The LPGS must package with L1 products all related data necessary to interpret those products, as specified in Applicable Document 2.
- The LPGS must provide the capability to assess L1 product quality, as specified in Applicable Document 2.
- The LPGS must provide the capability to transfer L1 files, as specified in Applicable Document 2.
- The LPGS must provide the capability to store L1 products temporarily for up to 72 hours.
- The LPGS must generate L1R and L1G products consistent with performance specifications provided by the Landsat 7 science office (see Applicable Document 2).
- The LPGS must be able to ingest a volume equivalent to three WRS scenes' worth of standard L0R data for each L1 product request.
- The LPGS must provide the capability to transfer the equivalent of a minimum of 28 L1 scenes per day.

2.2 LPGS Design Assumptions

An *LPGS design assumption* is defined as a statement that has significant consequence for the design that is accepted as true but that cannot be traced to baselined project documents. The LPGS design is based on the following assumptions:

- LPGS does not perform processing on subsampled Level 0 data.
- The L1 geometric processing subsystem (GPS) and radiometric processing subsystem (RPS), developed by IAS, are available for integration by LPGS.
- The Level 3 requirements for the ECS will be baselined. In support of L1 processing, the ECS performs the following functions:
  - Accepts user orders for L1 products
  - Accepts, as part of the user order, the following types of information: user parameters, scene identifier (ID), interval specification, parameter subset (i.e., band) specification. orientation, grid cell size, map projection, output format, resampling interval, media type, shipping information, billing information, input granule identification, calibration method, and parameters specific to each map projection
  - Accepts standing orders for L1 products
  - Provides pricing for L1 orders before accepting the order
  - Accepts order cancellation requests from users for previously ordered L1 products
  - Accepts order status requests from users
  - Provides order status to users
  - Stores documentation (e.g., algorithm descriptions) and production process software for the L1 production processes
  - Makes documentation and production process software available to users on request
  - Sends processing requests to LPGS for the generation of L1 products
  - Forwards processing cancellation requests to LPGS for production process cancellation
  - Provides the capability to distribute at least 25 L1 equivalent WRS scene products each day to users
  - Queries LPGS for the status of processing requests that have been submitted but not yet received
- The LPGS does not perform precision correction or terrain correction for ground control points during L1G production. The LPGS does, however, perform resampling for geometric correction and geographic registration to map projections.

2.3 LPGS Design Constraints

An *LPGS design constraint* is defined as an external factor that limits system design options or mandates specific elements in the design. The LPGS design is constrained by the following considerations:

- The LPGS interface hardware must be compatible with the existing Earth Resources Observing System (EROS) Data Center (EDC) network configuration.
- The LPGS interface hardware must be compatible with future ECS specifications.
- The LPGS interface hardware must be compatible with IAS specifications.
- The LPGS interface hardware must be compatible with DHF specifications.
- The LPGS must be able to produce L1 digital images in one of three output formats: Hierarchical Data Format (HDF), GeoTIFF, and FAST. Therefore, the LPGS must use associated application software and applicable tools to accommodate these output formats.
- Issues of cost and maintainability require the use of commercial off-the-shelf (COTS) hardware. Using COTS hardware limits hardware configuration options and performance capabilities.

2.4 System Design Approach and Methodology

This section provides a brief description of the methods used to specify the LPGS system design. Section 2.4.1 describes the system design specification process. Section 2.4.2 describes the structured analysis notation used in this document. Section 2.4.3 describes the automated tools used in the system design process.

2.4.1 Approach and Methodology

The LPGS system design has been developed using the SEAS System Development Methodology (described in Reference Document 20) tailored to suit the LPGS project environment. Because the LPGS is to be based on reusing software from the IAS, many of the steps were shortened by reusing and modifying portions of the IAS design. The LPGS system design has been accomplished by performing the following major activities:

- Analysis of the LPGS system requirements and operations concept to identify system design drivers, constraints, and assumptions
- Functional decomposition of LPGS system requirements through structured analysis to define the scope of the LPGS system, its subsystems, and their interfaces
- Analysis of the LPGS system requirements and operations concept to determine the allocation of LPGS requirements to LPGS system, hardware, software, and operations
- Development and analysis of an LPGS architecture that meets system requirements and is based on well-defined assumptions and constraints and meets or surpasses a set of predefined evaluation criteria

- Development and analysis of an LPGS hardware configuration adequately sized to meet or exceed the LPGS workload and performance requirements stated in the F&PRS
- Development and analysis of an LPGS software architecture that is based on LPGS structured analysis, conforms to the selected hardware configuration and constraints, and allows for the maximum use of COTS items in its implementation
- Technical analysis to support the LPGS system design process, including the following studies:
  - LPGS workload and traffic analysis
  - Data storage and communication studies
  - Reliability, maintainability, and availability (RMA) analysis
  - Operational timeline analysis
  - System and operational cost analysis
  - Software sizing analysis
  - System/implementation risk analysis
  - Selection of COTS and software-based tools; building on IAS team results
- Generation of the LPGS system design specification
- Analysis of the IAS preliminary interface data descriptions (IDDs)
- Identification of LPGS issues that, when resolved, may affect the LPGS system design

The following sections briefly describe the LPGS system architecture, hardware, and software selection approaches.

2.4.1.1 System Architecture Selection

The LPGS system architecture was developed by

- Evaluating the IAS system architecture
- Modifying the IAS system architecture to accommodate the higher throughput requirements of the LPGS
- Modifying the IAS system architecture to support pipeline processing rather than analysis as the primary requirement

Table 2-1 shows the drivers used in making the architecture selection.

Table 2-1. LPGS Architecture Evaluation Criteria

Criterion	Rationale
Compatibility with IAS	The reuse of IAS processing software reduces cost and development time for the LPGS. Reuse of IAS analysis tools reduces cost and development time and also allows for cross-training of personnel between LPGS QA and anomaly analysis and IAS calibration analysis.
Pipeline processing	The basic purpose of the LPGS is to produce data products, not to analyze data.
Throughput	The LPGS must process 25 scenes per day.
Compatibility with other EGS systems	The LPGS is to be a part of the EGS, and taking advantage of existing EGS external interfaces minimizes cost and development time.

2.4.1.2 Hardware Configuration Selection

The LPGS system architecture was developed by

- Starting with the IAS hardware architecture
- Modifying the IAS hardware architecture to accommodate the internal network throughput required for the higher volume requirements of the LPGS
- Modifying the IAS hardware architecture to accommodate the data flow management required for transferring data to and from the ECS for production processing

2.4.1.3 Software Architecture Selection

The LPGS software architecture was developed by

- Starting with the IAS subsystem definitions
- Modifying the IAS software architecture to accommodate the requirements of a production processing system
- Decomposing LPGS functional requirements through structured analysis to produce more detailed requirements
- Evaluating the resulting architecture based on criteria described in Table 2-2, with emphasis on the functional cohesion of subsystems and the coupling between them
- Repartitioning the subsystems and reevaluating until the resulting architecture satisfies the evaluation criteria

Table 2-2. LPGS Software Architecture Evaluation Drivers

Criterion	Rationale
Coupling	Coupling measures the strength of association between LPGS software subsystems. The LPGS software should be designed in such a way that subsystems are loosely coupled, and modification or replacement of one subsystem does not have a serious impact on other subsystems.
Cohesion	Cohesion measures the strength of association of elements within LPGS software subsystems. The LPGS software should be designed in such a way that each subsystem represents a functionally cohesive segment of the LPGS software system.
Reuse	The LPGS software architecture should maximize potential software reuse from IAS and other sources (including COTS products that might meet all or the majority of the requirements for a given subsystem).

2.4.2 Structured Analysis Conventions

Structured analysis for LPGS system design uses Yourdon and Constantine structured analysis notation conventions, illustrated in Figure 2-1. Products of structured analysis for LPGS system design consist of the top-level or Level 0 data flow diagrams (DFDs) and context diagrams. A DFD is a logical, graphical representation of data transformations performed by a system or subsystem on its input to produce its output. A context diagram is a special top-level DFD that names the system and subsystems to be designed and that defines the bounds of a system or subsystem in terms of the data it receives and generates.

2.4.2.1 Data Dictionary

The data dictionary (DD) is the single LPGS repository for each unique data flow, data store, and any acronyms or other items that are defined in the DFDs but are not part of a typical user's vocabulary. Each DD must contain the name of the item, all aliases by which the item is known, a definition, and any notes or comments to explain the item further. If the defined item contains other items, the defining items must be listed in addition to the description. The name of the DDE must conform to the LPGS naming convention.

2.4.3 Design Tools

CADRE Teamwork is the structured analysis tool that the LPGS system designers use. Teamwork supports the Yourdon and Constantine method of structured analysis. System designers used Teamwork to create the LPGS DD, context diagrams, and DFDs. Teamwork provides checking features that allowed the designers to verify the completeness and accuracy of the generated diagrams.

The Marconi Requirements and Traceability Management (RTM) tool is used to map the LPGS system requirements to the subsystem that will address them. RTM interfaces with a COTS database to track and manage the system requirements. RTM also interfaces with Teamwork by

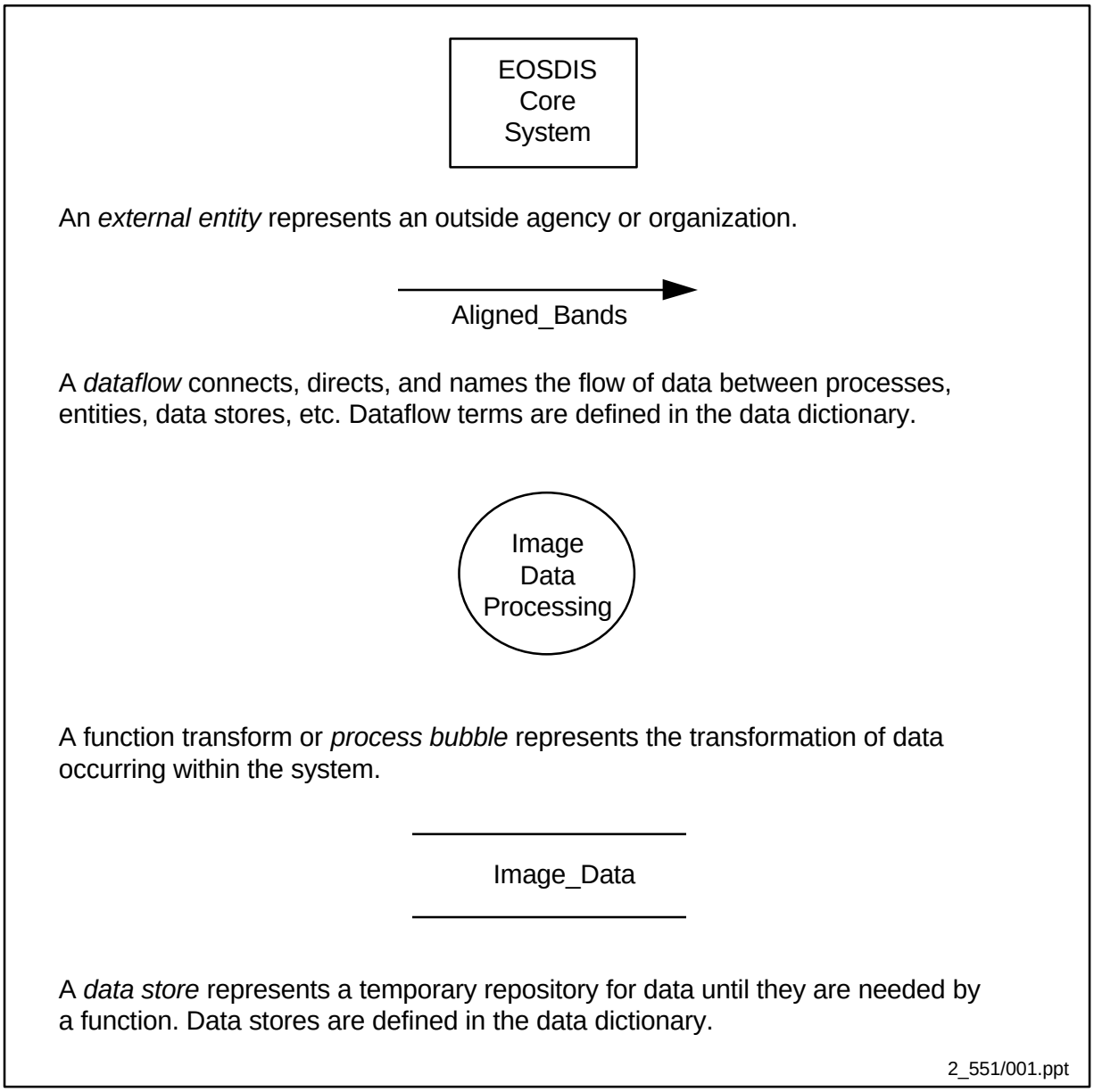


Figure 2-1. LPGS Structured Analysis Conventions

allowing the software developer to create links between the graphical representations of each subsystem, created by Teamwork, and the requirements that each satisfies. RTM assists the software developers in ensuring that each requirement is being addressed during the system design phase, is satisfied during the implementation phase, and is verifiable during the test phase of the software life cycle.

2.5 LPGS System Architecture

This section describes the LPGS system architecture. Where appropriate, references to summary results from system design studies are provided. Detailed results from LPGS system design activities, analysis, and trade-off studies are provided in Appendix C

The LPGS system design consists of a reference architecture (system concept), the hardware configuration items (HWCIs) and software configuration items (SWCIs) that support that architecture, and operations considerations based on the system architecture.

The LPGS reference architecture is based on structured analysis of LPGS functional characteristics and data flows. Its two major components are the LPGS functional flow and interconnect architectures. The LPGS functional flow architecture consists of a set of DFDs, including the LPGS context diagram and the Level 0 diagram. These diagrams are shown in Figures 2-2 and 2-3, respectively. The LPGS context diagram focuses on LPGS external data flows whereas the Level 0 diagram provides a breakdown of the LPGS into its subsystems and identifies intersubsystem data flows. The LPGS interconnect architecture provides a system block level (hardware) interconnect view of the LPGS, showing allocation of LPGS subsystems to system blocks to convey the LPGS implementation concept. Figure 2-4 shows the LPGS system architecture.

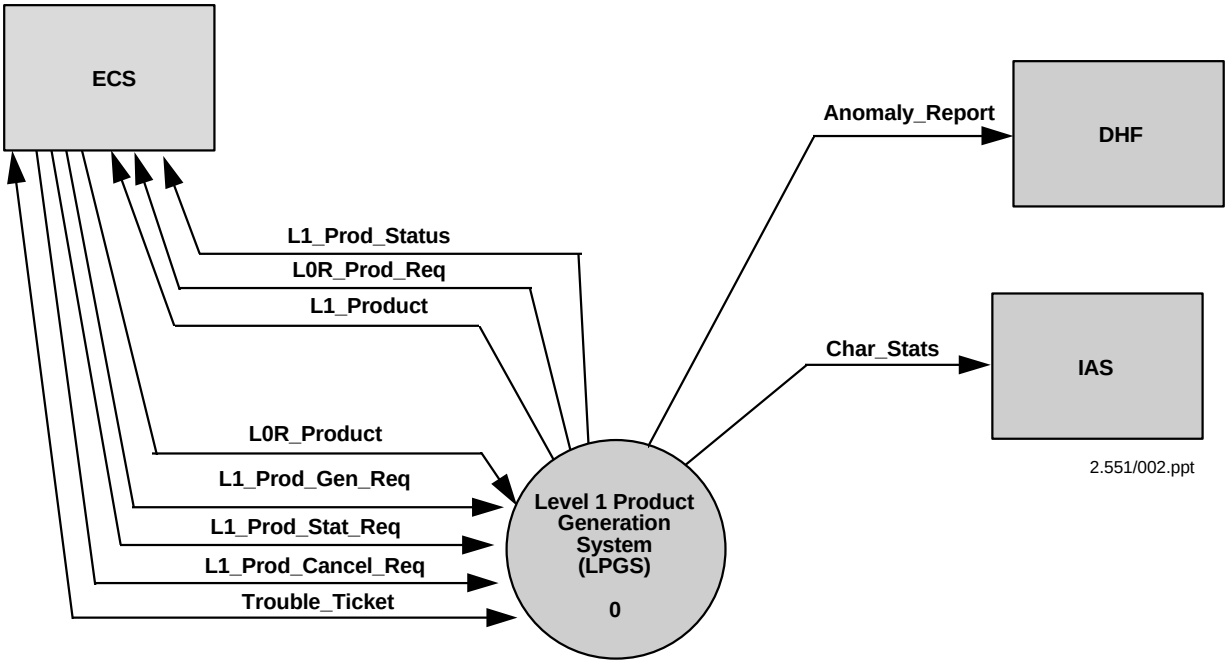


Figure 2-2. LPGS Context Diagram

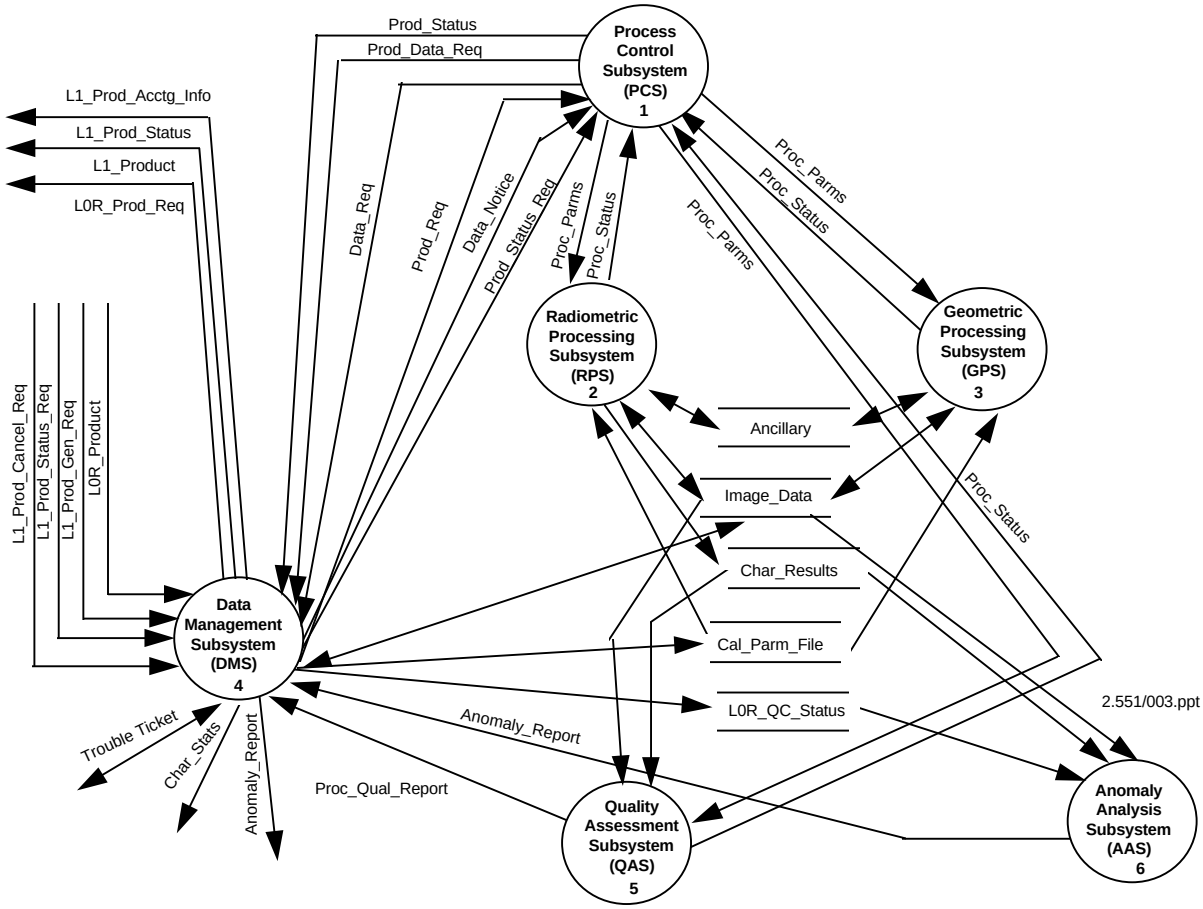


Figure 2-3. LPGS Level 0 Diagram

2.5.1 LPGS Functional Flow Architecture

The LPGS Level 0 diagram is based on an analysis and allocation of the LPGS system requirements, contained in Applicable Document 2, and their synthesis to define the LPGS subsystems and interfaces. The LPGS consists of the following subsystems:

- Data management subsystem (DMS)
- Process control subsystem (PCS)
- Radiometric processing subsystem (RPS)
- Geometric processing subsystem (GPS)
- Quality assessment subsystem (QAS)
- Anomaly analysis subsystem (AAS)

The LPGS system architecture serves as the main driver for the LPGS software architecture. Specific details on the LPGS subsystems shown in this architecture are provided in Section 3.

2.6 LPGS Hardware Design

This section specifies the LPGS hardware design. Section 2.6.1 lists and describes each HWCI and hardware component (HWC). Section 2.6.2 explains how the hardware design satisfies LPGS performance requirements.

The LPGS hardware design and external interfaces are shown in Figure 2-4. The overall design is based on a distributed network of workstation and server class platforms on a high-speed local area network

2.6.1 Hardware Configuration Items

The LPGS hardware design is divided into five HWCIs partitioned by functionality. The HWCIs are described in the subsections that follow.

2.6.1.1 Level 1 Processing HWCI

The Level 1 processing HWCI is a network server system that provides the storage for incoming data from the ECS and for outgoing product data.

The online storage devices are high performance redundant-array-of-inexpensive-devices (RAID) technology to ensure that no data are lost in the event of a disk drive failure.

The L1 processing HWCI uses a dual-network connection. One connection provides connectivity to the internal network HWCI, which has a low performance demand for communications interface. The second connection provides fiber distributed data interface (FDDI) connectivity to the wide area network for interface with external entities, such as the ECS and DHF, and to the LPGS workstation.

The production HWCI also has a tape drive for the backup of data and, in an emergency, for offloading of production output data for transfer to the ECS. In addition, the drive is used to routinely offload digital images to tape for printing on the color printer.

The compute server for performing the science data processing functions provides the compute power necessary to process the Landsat 7 L0R images to L1R or L1G. A failover platform is available as part of the backup/maintenance system.

The local storage on the system is used to hold the system and application software. The input data and the output products are expected to be stored on the L1 processing HWCI disk array until the output products are transferred to the ECS.

Connectivity with other HWCIs in the LPGS is through the internal network HWCI or the FDDI.

2.6.1.2 Quality Assessment/Anomaly Analysis HWCI

The quality assessment/anomaly analysis HWCI is a set of up to two display workstations for the visual assessment of processed data and the investigation of processing anomalies.

The local storage is used to hold the system and application software. Scenes to be analyzed are kept on the L1 processing HWCI disk array. Images can be written to an 8-millimeter (mm)

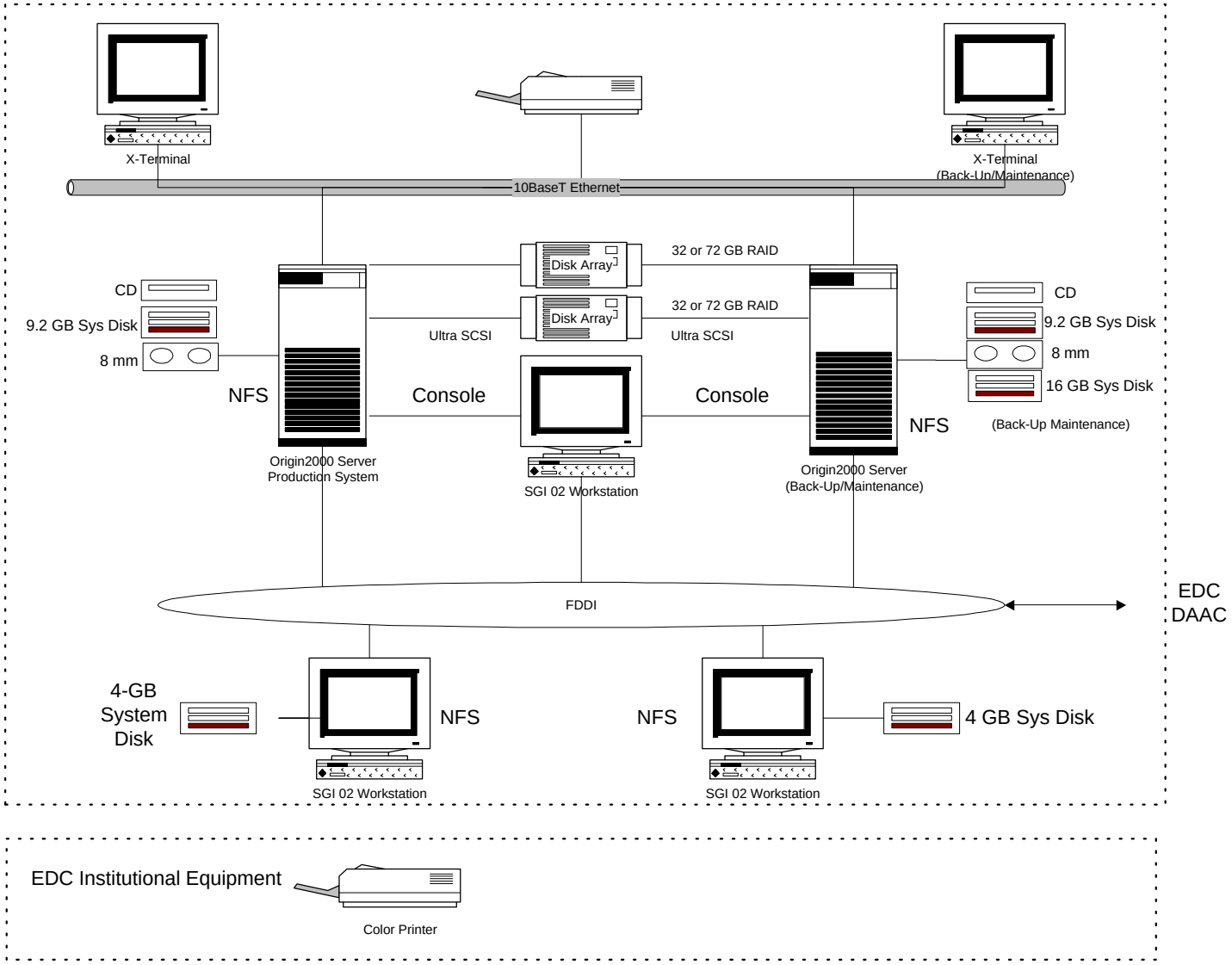


Figure 2-4. LPGS Hardware Design

digital audio tape (DAT) drive for offloading to the EDC color fire printer included in the printer HWCI.

Connectivity with other HWCIs in the LPGS is through the FDDI.

2.6.1.3 Internal Network HWCI

The internal network HWCI provides the interface between the operations interface HWCI and a component of the printer HWCI to the rest of the HWCIs.

The network is a 10-megabytes-per-second (Mbps) Ethernet network (10BaseT) in a star configuration. At the center of the star is an Ethernet hub.

2.6.1.4 Operations Interface HWCI

The operations interface HWCI is a display monitor that provides a text and graphical interface for the production control operator. This HWCI consists of an X-Windows-capable color monitor and keyboard connected to the console ports of the production HWCI server platform(s) through the internal network HWCI.

2.6.1.5 Printer HWCI

The printer HWCI consists of a black/white printer that provides a hardcopy interface for printing reports and analysis findings and a high quality color film recorder which provides a hardcopy interface for printing digital images for analysis. The color film recorder is currently installed at the EDC facility as part of its suite of institutional peripheral and support equipment, and has no network connectivity to the remaining LPGS HWCIs.

2.6.2 Mapping of Software Subsystems to HWCIs

Table 2-3 shows the mapping between the software subsystems identified in Section 2.7 and the HWCIs identified in this section. Because the LPGS is a distributed system, mapping between the HWCIs and the subsystems is not one-to-one.

Table 2-3. Allocation of HWCIs to Subsystems

HWCI	PCS	RPS	GPS	QAS	AAS	DMS
L1 processing	X	X	X	Automatic		X
Quality assessment/ anomaly resolution				Manual	X	
Operations interface	X					
Internal network	X					X
Printer	X			X	X	

2.6.3 Hardware Sizing and Performance Analysis

The sizing and performance analysis for the LPGS HWCIs is presented in this section as throughput capacities for each HWCI. The following assumptions were made for the sizing:

- The system must be able to accommodate scenarios in which 100 percent of the requests are for processing data equivalent to three contiguous L0R scenes to L1G.
- The size of a L0R product is 0.5 GB.
- Calibration data and the calibration parameter file from the ECS total 41 MB for each L0R product.
- L1R produces 1.3 GB for each L0R scene.
- L1G produces 1.3 GB for each L0R scene (resampled to 25 meters).
- Processing can be either serial or parallel. Because the requirement is to process 25 L0R scenes each day, no step may take longer than 50 minutes for each L0R scene in the request (accommodates a 10-percent increase in throughput).

2.6.3.1 Level 1 Processing HWCI

This HWCI must support simultaneous internal and external network transfers, with no transfer taking more than 50 minutes for each L0R scene averaged over a 3-day period, as shown in Table 2-4.

Table 2-4. Simultaneous Data Transfers From/to the L1 Processing HWCI

Source	Destination	Network	Data To Be Transferred
ECS	L1 processing	External	One L0R product
L1 processing	ECS	External	One L1 product
Quality analysis/ anomaly resolution	L1 processing	Internal	One L1 image

In addition, the L1 processing HWCI must have sufficient capacity to manage the processing queues. The selection of the platform, central processing unit (CPU), and memory for this HWCI is based on a benchmark of data transfers in a network environment similar to that expected for LPGS.

Table 2-5 contains the disk storage requirements for the L1 processing HWCI. The storage is sized to hold the L0R inputs for a total of three scenes (this total includes the associated calibration inputs), the L1 outputs for a total of 25 scenes for 3 days, and three scenes in reprocessing, plus an additional margin of 25 percent.

Table 2-5. L1 Processing HWCI Disk Array Storage Requirements

Location	Disk Space Required
L0R products	1.5 GB
3 days of L1 products	105 GB
1 day of reprocessed data	4.2 GB
25-percent margin	27.7 GB
Swap space	3 X real memory

In addition to this storage, a swap space equal to at least three times the real memory of the system is provided.

Two similar platforms, one for production and one for backup/maintenance, are procured. The production platform throughput is 25 scenes per day. The second platform is available for developing and testing new or modified processing software. Either of the two platforms can be used operationally as needed.

Table 2-6 shows the disk space requirements for each platform. Requirements for system and application software and swap space are included.

Table 2-6. L1 Processing HWCI Workstation Disk Storage Requirements

Location	Disk Space Required
System/application software	9.2 GB
Swap space	3 X real memory

2.6.3.2 Quality Assessment/Anomaly Analysis HWCI

Two workstations are provided for use in both visual QA and anomaly resolution.

Table 2-7 shows the disk sizing for each of these platforms. Similar requirements for system and application software and swap space are included as for the Level 1 processing HWCI.

Table 2-7. Quality Assessment/Anomaly Analysis HWCI Disk Storage Requirements

Location	Disk Space Required
System/application software	4 GB
Swap space	3 X real memory

2.6.3.3 Internal Network HWCI

The requirements for data transfer over this network are less than 10 percent of the available bandwidth capability of the 10BaseT Ethernet.

2.6.3.4 Operations Interface HWCI

Delays due to contention with file transfer will not affect the average system throughput time and will be less than 30 seconds.

2.6.3.5 Printer HWCI

These requirements are based on requirements for printing black and white text and graphics reports and digital color images for analysis.

2.7 Software Configuration Items

The LPGS software architecture is outlined in this section. The system support software is discussed in Section 2.7.1. The application software, including the LPGS software development considerations and the LPGS subsystems, is presented in Section 2.7.2.

2.7.1 LPGS System Support Software

The LPGS system software consists of COTS software components that either satisfy LPGS requirements directly or support LPGS application software. LPGS system support software consists of system software SWCIs and COTS application SWCIs and nondevelopment item (NDI) components. LPGS system software SWCIs include the following:

- IRIX 6.2 operating system
- FDDI device interface
- Transmission Control Protocol/Internet Protocol software
- Device drivers for system peripherals

COTS application SWCIs include the following:

- Oracle Database Management System (DBMS)
- Oracle SQL*Forms and X-Motif graphical user interface (GUI) development tools
- National Center for Supercomputing Applications (NCSA) HDF
- Interactive Development Language (IDL)
- FAST application software and toolkit
- GeoTIFF application software and toolkit
- Environment for visualizing imagery (ENVI)

NDI support application SWCIs incorporated into the IAS design will include the following ECS applications:

- Application program interfaces (APIs) to facilitate ECS “push” of L0R data upon LPGS request
- APIs to interface with ECS insert service for distribution of L1 products

Detailed descriptions of LPGS system support software appear in Section 4.

2.7.2 LPGS Application Software and Subsystems

This section describes the application software architecture design considerations and presents a brief functional overview of LPGS subsystems.

The LPGS application SWCIs correspond to the subsystems defined in Section 2.5, Figure 2-3. The purpose and basic functionality of each subsystem are as follows:

- **Data management subsystem (DMS)**—The DMS maintains and provides access to LPGS data stores. The DMS handles communication protocols with LPGS external interfaces, ingests and formats files for use by other LPGS subsystems, and provides cursory quality checks where needed. The DMS provides formatting and packaging of L1 output and makes these data available to external systems. The DMS also maintains LPGS disk space used as temporary storage for data from ingested files.

- **Process control subsystem (PCS)**—The PCS controls LPGS production planning and processing. The PCS receives product generation requests and sets up, monitors the status of, and controls processing of LPGS work orders. The PCS manages and monitors LPGS resources and provides processing status in response to customer and operator requests. The PCS also initiates requests for L0R products in support of work order setup and processing control.

- **Radiometric processing subsystem (RPS)**—The RPS converts the brightness of the L0R image pixels to absolute radiance in response to user requests and in preparation for geometric correction. The RPS performs radiometric characterization of L0R images by locating radiometric artifacts in images. The RPS provides results of characterizations performed and processing status for use by external elements and other LPGS subsystems. The RPS corrects for the radiometric artifacts found using applicable algorithms, then converts the image to absolute radiance using internal calibrator data.

- **Geometric processing subsystem (GPS)**—The GPS creates systematically corrected L1G imagery from L1R products. The GPS prepares a resampling grid, recreates the L1R image within the grid, and applies one of three optional resampling techniques. The GPS performs sophisticated satellite geometric correction to create the image according to the user- specified map projection and orientation.

- **Quality assessment subsystem (QAS)**—The QAS generates and assembles postproduction information about image artifacts and effects that were not corrected, and it produces a summary of the processed image quality. The QAS performs QA after radiometric and geometric correction of images has been made. The QAS provides tools for analyzing images automatically and manually, through visual inspection.

- **Anomaly analysis subsystem (AAS)**—The AAS analyzes L1 images and associated postproduction information about image artifacts and effects to resolve image production anomalies. The AAS provides results of such problem analysis to the DMS for forwarding to the DHF for further investigation.

A detailed description of each subsystem is presented in Section 3.

2.8 LPGS Test Support Items

The LPGS system design provides additional compute power to accommodate testing without impact to operations. No CIs are explicitly allocated for test support. Calibration images, or “known good scenes” of ETM+ data are used by the LPGS for initial verification and regression testing of processing capabilities. The LPGS compares test image results with previously certified test images to verify successful processing.

2.9 Integration and Test (I&T) for LPGS

This section presents the roles and responsibilities of the development and test organizations as they relate to the buildup, integration and testing of the IAS system.

The specific types of tests planned for LPGS and the responsibilities of each organization related to these test is presented in Table 2-8.

Testing through build integration is the responsibility of the development organization. The test team will support each of the development groups as they concurrently develop their parts of the LPGS.

Table 2-8. Planned Tests and Organizational Responsibilities

Test Phase	Test Objective	Performed By
Test planning	Develop a detailed test plan that details the methods and resources that will be used in testing	Test lead
Unit test	Verify path coverage and unit functionality	Unit developer
Module test	Integrate unit into modules and verify interface within modules	Development organization
Module integration test	Integrate modules into a functional subsystem to test interface between subsystems	Development organization
Build integration	Integrate subsystem to test external interfaces	Development organization
Integration test	Verify interfaces between subsystems	Test and development organization
System test	Same as acceptance test, with emphasis on compliance with requirements	Independent test organization
Acceptance test	Verify ability to fulfill the operational need, to comply with requirements, to provide functionality of entire system, ability to support error processing, and ability to support external interfaces; emphasis on ability to fulfill the operational need	Operations organization
Mission readiness test	Verify that the system is ready to meet its requirement in an operational context	Operations organization
Operation	Verify a collection of activities performed using hardware, software, and human action to meet major milestones of the mission	Operations organization

Section 3. System Design

This section provides a detailed description of the LPGS subsystems. For each subsystem, the allocated requirements, interfaces, functional description, major data items, hardware, and software are described. The design presented here specifies the architecture of the LPGS without backup maintenance.

3.1 Data Management Subsystem

The data management subsystem (DMS) is responsible for

- Handling communication protocols with LPGS external interfaces
- Ingesting externally provided files and formatting them for LPGS use
- Receiving transmitted requests and messages
- Performing cursory quality checks to verify that Level 0 data files are properly associated with a specific image
- Populating temporary storage with the files needed to perform L1 processing of the specific image
- Formatting/packaging the completed L1 product
- Producing a variety of LPGS reports
- Distributing files to external interfaces
- Maintaining LPGS disk space

3.1.1 Requirements Allocation

The complete mapping of LPGS system requirements to subsystems, including the DMS, is provided in Appendix A.

3.1.2 Interfaces

Figure 3-1 illustrates the DMS's system context and external interfaces. Image and ancillary data are received from the ECS by using the file transfer protocol (FTP) and other protocols. A similar process is followed when distributing LPGS products to ECS and IAS. As depicted in Figure 3-1, the DMS also coordinates L1 processing of a L0R product and handles LPGS reporting requirements.

The DMS receives L1_Prod_Gen_Req messages from ECS and forwards them, as Proc_Req messages, to the PCS. After the PCS processes the Prod_Req, it returns a Data_Req message to the DMS. The DMS formulates a L0R_Prod_Req, which is transmitted to ECS, to obtain the L0R data files needed to perform LI processing.

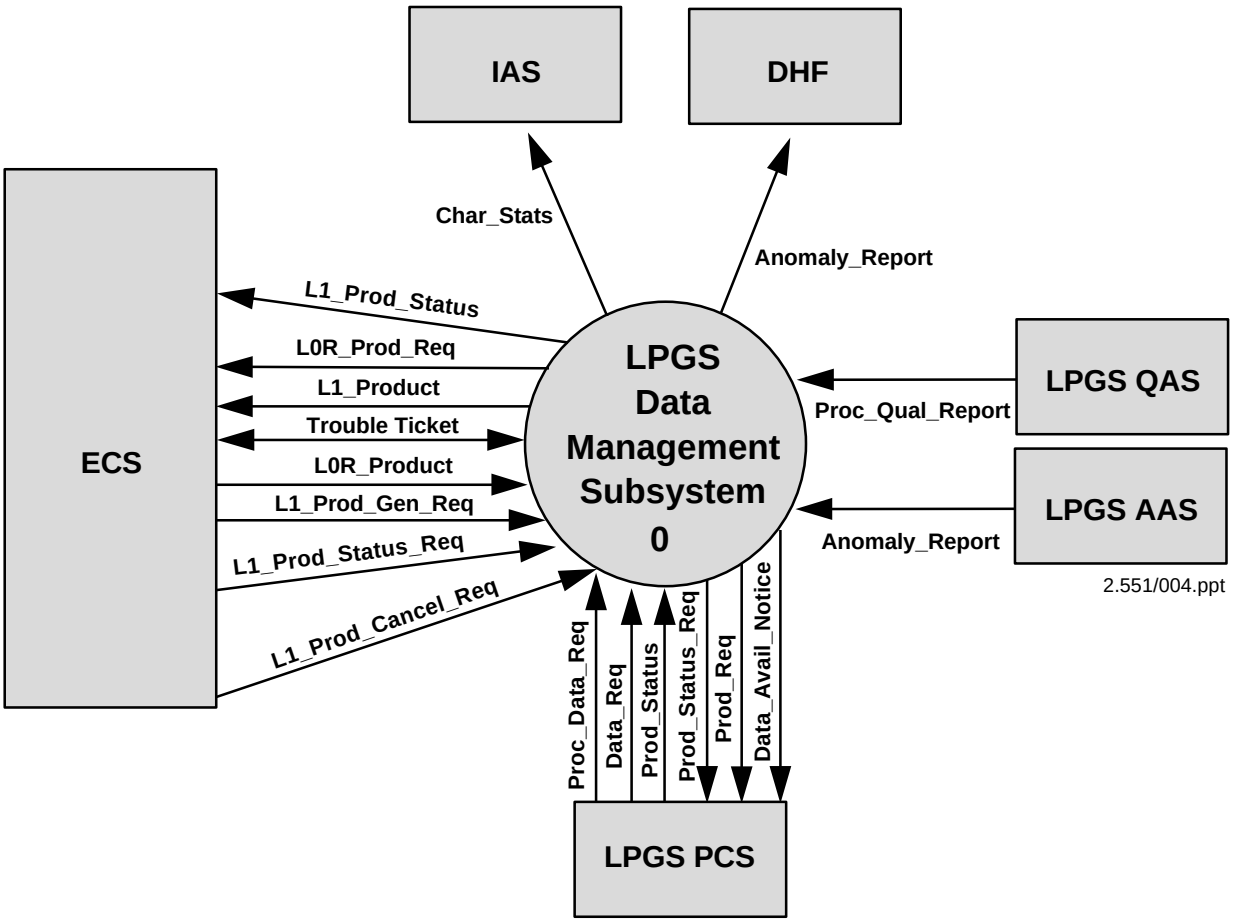


Figure 3-1. DMS Context Diagram

As L0R product files (L0R_Product) are received from ECS, the DMS

- Performs quality checks and places the results in the L0R Quality Check Statistics (L0R_QC_Stats) data store
- Places the calibration parameter file (Cal_Parm_File), Level 0 image data (Image_Data), and ancillary data (Ancillary) into temporary storage
- Issues a data availability notice (Data_Notice) to the LPGS PCS

The DMS receives Proc_Qual_Report from the QAS after L1 product processing is completed. The Proc_Qual_Report is used to create, depending on final output format, metadata files and metadata values. The DMS performs final product formatting and assembly and sends a Data_Notice to the PCS to trigger final QA of the product. Upon successful completion of final product QA by QAS, a Proc_Qual_Report is received from DMS, ECS is notified of the availability of the formatted L1 product, and the DMS coordinates distribution of the L1 product (L1_Product) to ECS.

The DMS serves as a repository and distribution point for several LPGS reports. The DMS ingests anomaly reports (Anomaly_Reports) from the AAS subsystem. The anomaly reports (Anomaly_Report) go to DHF. The DMS also extracts the RPS-generated radiometric characterization output (Char_Stats) from temporary data storage and sends it to the IAS.

The DMS is also the interface for exchanging trouble tickets with the ECS. Trouble tickets initiated by LPGS operators are transmitted to the ECS for processing. Trouble tickets received from ECS are resolved through the anomaly analysis subsystem.

3.1.3 Functional Description

DMS's primary functions are described in the subsections that follow.

3.1.3.1 Data Ingest

The Data Ingest function handles communications with external data sources and receives L0R Products for use in L1 processing.

The DMS receives an L1 product generation request form from the ECS. The DMS extracts the L1 processing information from the request and forwards this information, in the form of a Prod_Req, to the PCS. After a work order is generated, the PCS sends DMS a Data_Req, which results in DMS's issuing a request for the L0R product electronically from the ECS. The L0R products are received by DMS and placed in a temporary storage area for use within LPGS, as shown in Table 3-1.

Table 3-1. Data Ingest Temporary Storage

LPGS Internal Data Store	Used by LPGS Subsystem(s)
Cal_Parm_File (Calibration parameter file)	Radiometric processing (RPS), anomaly analysis (AAS), QA (QAS), GPS
Image_Data (Level 0 image data)	RPS, geometric processing (GPS), AAS, QAS
Ancillary (Ancillary data, for example, spacecraft attitude, ephemeris, PCD, MSCD, and IC data)	RPS, GPS

The DMS Ingest function also provides an interface for receiving processing status requests, production cancellation requests, and trouble tickets from ECS. The DMS forwards the processing status and production cancellation requests to the PCS and receives responses from the PCS; these responses are then forwarded to ECS.

3.1.3.2 L0R Data Quality Check

The L0R data product consists of multiple files. The DMS does a quick check to verify that all the files are related to the same time period and subinterval. The DMS conducts a quality check to verify that the L0R image is a suitable candidate for L1 processing. The results of these quality checks are logged into the L0R Quality Check Statistics data store. The DMS also removes errors

from and verifies format 1 and 2 PCD and MSCD files and produces a single consensus PCD and MSCD file from the two formats.

3.1.3.3 Format/Package Product

The DMS Format and Package function formats and packages L1 products and processing reports. For L1 products, when RPS, QAS, and if applicable, GPS processing is complete, DMS formats the L1 product into three possible formats:

- HDF-Earth Observing System (EOS) unencapsulated (L1R and L1G)
- EOSAT FAST-Format B (L1G only)
- GeoTIFF (L1G only)

For the HDF-EOS unencapsulated package, the DMS includes the files shown in Table 3-2, as well as an HDF index file. For the FAST and GeoTIFF formats, metadata and attitude and ephemeris data are embedded within the formatted image files.

The DMS assembles L1 processing information into accounting reports on a periodic or operator-initiated basis. In addition, the DMS accepts operator input to formulate trouble tickets for reporting system or operational problems.

Table 3-2. L1 Product Contents

	HDF-EOS Unencapsulated Format		FAST/GeoTIFF
Component	**L1R**	**L1G**	**L1G**
L1 digital image	X	X	X*
Calibration parameter file	X	X	
PCD	X		
MSCD	X		
Metadata (including processing quality information)	X	X	
Internal calibrator data	X		
Geolocation table	X	X	

* Format embeds metadata and attitude/ephemeris information in file that contains image.

3.1.3.4 Data Transfer

As products are available for transfer to external sources, the DMS oversees the electronic transfer process.

The DMS transmits L0R product requests to ECS in response to data requests received from PCS. The DMS notifies ECS of the availability of each formatted L1 product.

The ECS acknowledges receipt of this notification, as well as completion of retrieval of the L1 product file from LPGS.

The DMS also distributes AAS-generated anomaly reports to the DHF. Radiometric and geometric processing characterization statistics are shipped to the IAS. The details of each of these interfaces will be defined in the LPGS/DHF ICD and LPGS/IAS ICD (Applicable Document 6). On operator request, these and other reports are generated for LPGS use.

The DMS transmits trouble tickets to ECS as needed.

3.1.3.5 Manage Disk Space

The Manage Disk Space function performs traditional file management services, including establishing directories, allocating disk space, managing online and offline data stores, and performing backups to archive.

Each day, at a time designated and entered into the system by the subsystem operator, the LPGS automatically assesses system storage capacity. Expired L0R and L1 products are deleted. L0R data and intermediate products are deleted when the quality of the L1 product in final format has been successfully assured. L1 product files can be deleted after successful retrieval by ECS.

3.1.4 Data

This section describes the internal data flows that appear in Figure 3-1 and the data stores that support the DMS subsystem.

- **Ancillary**—Nonimage datasets needed for processing, including the PCD, MSCD, internal calibrator file, and metadata
- **Anomaly_Report**—See AAS
- **Cal_Parm_File**—Calibration parameter file provided by the ECS as part of L0R_Product. Cal_Parm_File is placed into temporary storage by the DMS; it contains the radiometric calibration parameters
- **Char_Stats**—DMS-generated report provided to the IAS; contains the characterization results from the RPS and GPS
- **Data_Notice**—Data availability notification sent to the PCS by the DMS on successful storage of L0R products received from the ECS
- **Data_Req**—See PCS
- **Image_Data**—ECS-supplied L0R image data (placed into temporary storage by DMS), plus RPS-generated L1R digital images and GPS-generated L1G digital images
- **L0R_Product**—L0R products received from the ECS include 0R image data for all requested bands, metadata, internal calibrator data, calibration parameter file, PCD, MSCD geolocation table and HDF index file

- **L0R_Prod_Req**—DMS request sent to the ECS asking for delivery of the identified L0R dataset
- **L0R_QC_Stats**—Statistics resulting from DMS analysis of L0R image product file consistency and completeness
- **L1_Product**—DMS-formatted L1 digital image with appended or embedded metadata and ancillary and quality information
- **L1_Prod_Cancel_Req**—A request received from the ECS to cancel work on a previously submitted L1_Prod_Gen_Req
- **L1_Prod_Gen_Req**—Request from the ECS asking LPGS to produce an L1 Product for a specific scene in accordance with user-specified options
- **L1_Prod_Status**—L1 production status and resource allocation information
- **L1_Prod_Status_Req**—Request from the ECS for a copy of the current LPGS L1 production status
- **Proc_Data_Req**—See PCS
- **Proc_Qual_Report**—See QAS
- **Prod_Req**—L1 product generation information and processing parameters extracted from L1_Prod_Gen_Req
- **Prod_Status_Req**—Request for processing status information sent to PCS by DMS
- **Trouble_Ticket**—A report of problems with a product generated by LPGS that the LPGS receives from the ECS

3.1.5 Subsystem Hardware

The DMS is hosted and executes on the L1 processing HWCI. See Section 2.6 for additional detail.

3.1.6 Subsystem Software

The DMS software includes COTS products in addition to custom-developed application code. Reuse of IAS developed software is also expected. It is anticipated that the following system, COTS, and NDI software are to be incorporated to provide some of the required system functionality:

- ftp software to handle ftp communications protocol
- ECS ingest service and other APIs to provide an interface for receiving and distributing data to the ECS
- HDF toolkit for accessing fields in the MSCD and PCD

- Oracle relational DBMS (RDBMS) for storing and retrieving L0 and L1 data, characterization, assessment, and correction results
- IRIX file management system for file general management services

3.2 Process Control Subsystem

The PCS is responsible for production planning in LPGS:

- Responding to production requests
- Setting up work orders for requested L1 products
- Queuing work order requests
- Controlling the execution of the work orders
- Managing and monitoring LPGS resources

3.2.1 Requirements Allocation

The complete mapping of LPGS system requirements to subsystems, including the PCS, is provided in Appendix A.

3.2.2 Interfaces

Figure 3-2 illustrates the PCS system context and external interfaces. The PCS receives L1 production requests (Prod_Req), data notices (Data_Notice), and LPGS schedule requests (Prod_Status_Req) from the DMS. The PCS extracts the L0R dataset identifier from each product generation request. At the appropriate time, the PCS uses this identifier to request that L0R products (Data_Req) be obtained by the DMS from ECS. The DMS notifies the PCS (Data_Notice) when the L0R products arrive from the ECS. When the PCS initiates processing of a specific L1 image, the PCS also places the user-specified processing parameters into internal temporary storage (Proc_Parms) for use by the RPS and GPS. In turn, these subsystems notify PCS when L1 processing is completed (Proc_Status). When notified that L1 processing and product formatting are completed, PCS provides processing parameters (Proc_Parms) to QAS to initiate automated or manual quality assessments of L1 images and formatting. In addition, the PCS receives requests for processing status (Prod_Status_Req) from DMS. Similarly, production status (Prod_Status) is provided to the DMS for transmission to ECS.

3.2.3 Functional Description

The primary functions of the PCS are described in the subsections that follow.

3.2.3.1 Set Up Work Order

When an L1 product generation request is received, the PCS generates a work order. This work order is added to the L1 processing queue. LPGS operator-generated reprocessing requests are also converted to work orders and placed in the queue. The work order contains information from

the original product generation request, including a customer identification, processing parameters, product request identifier, and L0R data identifier.

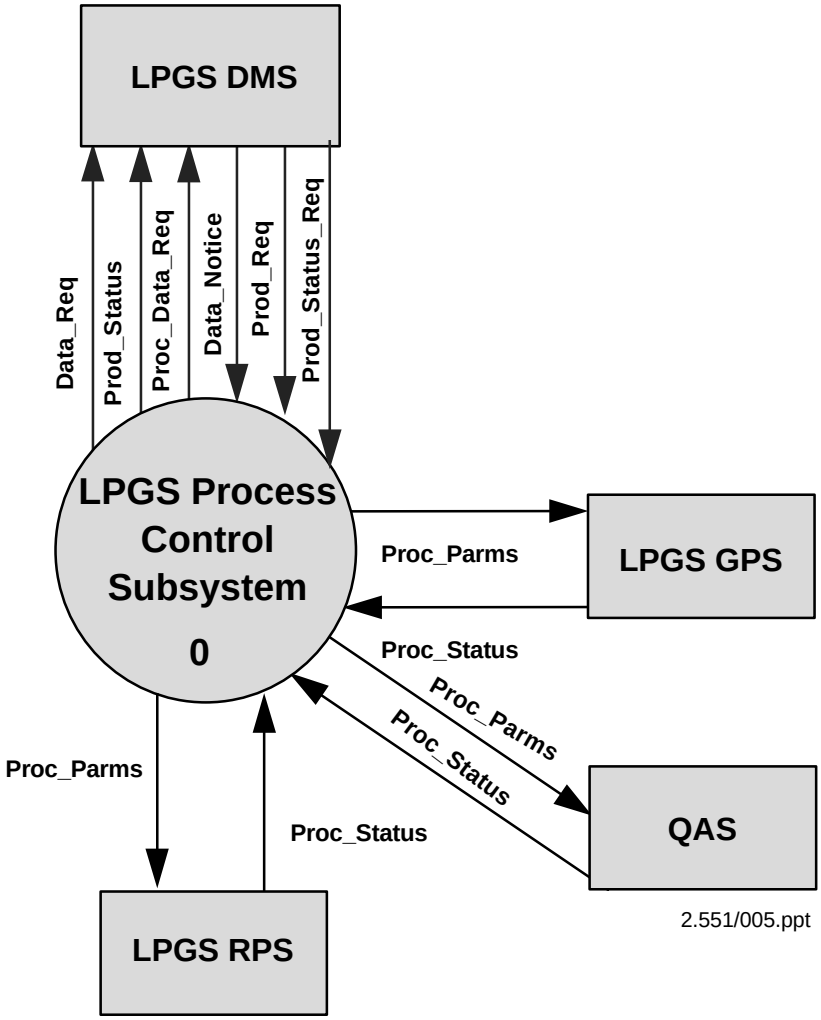


Figure 3-2. PCS Context Diagram

3.2.3.2 Control Processing

Work orders are by default processed on a first in, first out (FIFO) basis. Overrides are built into the system to alter the position of a work order in the processing queue. A L0R product request is sent sufficiently in advance to ensure that the data are available before the work order is executed within LPGS. When the LPGS DMS signals receipt of the L0R product, the work order's status is updated immediately.

When cancellation requests are received from the ECS, processing of the affected work order is terminated immediately. The LPGS system can also be configured to permit an alternative

approach to cancellation requests. This option would permit the LPGS operator to review the affected work order, confirm cancellation, and initiate process termination.

3.2.3.3 Manage LPGS Resources

Processing resources (e.g., disk space) are allocated for L1 data production. Receipt of a cancellation request for a queued work order translates to a de-allocation of resources, assuming that processing has not begun.

In response to a production status request or LPGS operator request, production status information is generated.

3.2.4 Data

This section describes the data flows that appear in Figure 3-2 and the data stores that support PCS.

- **Data_Notice**—See DMS
- **Data_Req**—Request sent to DMS to obtain L0R products
- **Proc_Data_Req**—LPGS PCS directive to LPGS DMS requesting that final product formatting and packaging be performed
- **Proc_Parms**—User-specified processing parameters, extracted by LPGS PCS from the Product_Req message
- **Proc_Status**—See RPS and GPS
- **Prod_Req**—See DMS
- **Prod_Status**—LPGS L1 production status provided to the DMS by the PCS
- **Prod_Status_Req**—See DMS

3.2.5 Subsystem Hardware

The PCS is hosted and executes on the L1 processing HWCI.

3.2.6 Subsystem Software

The PCS software will include custom developed application software, COTS, and system software. Extensive reuse of IAS custom applications software will be employed. ORACLE DBMS will be used for storing work order data and processing parameters. Oracle SQL*Forms will provide an interface for operator modification and review of work orders. Operating system and COTS software will be used for executing work orders, and monitoring and reporting on system resource usage. The PCS will use system-supplied X libraries and Oracle Forms.

3.3 Radiometric Processing Subsystem

The RPS is responsible for converting the brightness of the image pixels to absolute radiance. The Level 1R processing characterizes the quality and various features of the image. If the user request is for L1 geometric processing, radiometric processing precedes geometric corrections.

3.3.1 Requirements Allocation

The complete mapping of the LPGS system requirements to subsystems, including the RPS, is provided in Appendix A.

3.3.2 Interfaces

Figure 3-3 illustrates the context and external interfaces of the RPS. The RPS receives user- specified processing parameters (Proc_Parms) from PCS. Temporary storage is accessed to obtain

- L0R image data (Image_Data)
- Radiometric calibration coefficients from the L0R calibration data (Cal_Parm_File)
- Spacecraft ephemeris and attitude data and IC data (Ancillary)

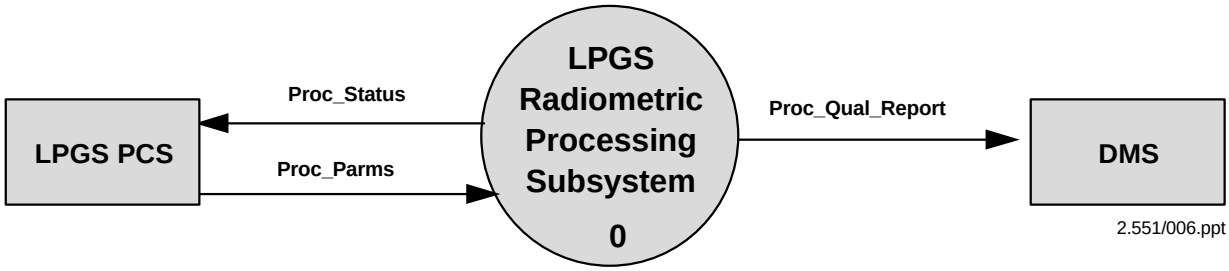


Figure 3-3. RPS Context Diagram

After the appropriate radiometric corrections are applied to the digital image, the RPS

- Stores the resulting L1 data image in temporary storage (Image_Data)
- Writes its characterization results to temporary storage (Char_Results) for subsequent analysis by the AAS and QAS and reporting by the DMS
- Sends its processing status results (Proc_Status) to the PCS
- Sends processing quality assessment results (Proc_Qual_Report) to DMS

3.3.3 Functional Description

The primary functions of the RPS are described in the subsections that follows.

3.3.3.1 Perform L1R Processing

L1R processing consists of five major processing steps described as following:

- **OR radiometric characterization—**In the 0R radiometric characterization step, several radiometric artifacts are located in the image and IC data so that these regions can be skipped during radiometric characterization.
- **Pre-IR correction**—The pre-1R correction step corrects for certain image artifacts before the conversion from digital numbers to absolute radiance. These corrections require the image and IC data to be logically combined, after which they are again separated.
- **ORC radiometric characterization**—The ORC radiometric characterization step repeats some of the 0R characterizations on the 0R corrected image to determine the effect of the pre-1R corrections.
- **IC data processing and IR radiometric correction**—The IC data for the process IC for the emissive (thermal) band is processed, and then the reflective bands, gains, and biases for each detector are calculated based on that detector's response to the shutter and the calibration lamps. The previously calculated gains and biases are applied to the scene data to convert digital numbers to absolute radiance.
- **IR radiometric characterization**—A final histogram analysis is performed to assess the quality of the corrections. Also, several artifacts are optionally corrected to produce a "cosmetically correct" image.

3.3.4 Data

This section describes the data flows that appear in Figure 3-3 and the data stores that support the RPS.

- **Ancillary**—See DMS
- **Cal_Parm_File**—See DMS
- **Char_Results**—Results of characterizations and scene-specific results of characterization algorithm execution; incorporates the results of the "Mask" and includes DL_Stats, IN_Stats, RN_Stats, A/D_Sat_Stats, QA_Stats, SCS_Stats, CN_Stats, IC_Gain, IC_Offset, and Scene_Bias
- **Image_Data**—See DMS
- **Proc_Parms**—See PCS
- **Proc_Status**—Processing status results from the RPS

3.3.5 Subsystem Hardware

The RPS is hosted and executes on the L1 Processing HWCI.

3.3.6 Subsystem Software

NCSA HDF tools will be used for retrieving L0R image, MSCD, PCD, and IC data and for writing out L1R image files. Oracle APIs will be used for storing and associating radiometric characterization results.

The RPS custom application software is to be reused from the IAS.

3.4 Geometric Processing Subsystem

The GPS creates systematically corrected L1G imagery from L1R products. The GPS provides processing status for use by external elements and other LPGS subsystems.

3.4.1 Requirements Allocation

The complete mapping of LPGS system requirements to subsystems, including the GPS, is provided in Appendix A.

3.4.2 Interfaces

Figure 3-4 illustrates the system context and external interfaces of the GPS. The GPS receives processing parameters from the PCS that are used to perform the systematic correction of the L1R image. From the processing parameters, the GPS identifies the L1R image and ancillary data that are extracted from the Image_Data and Ancillary data stores, respectively.

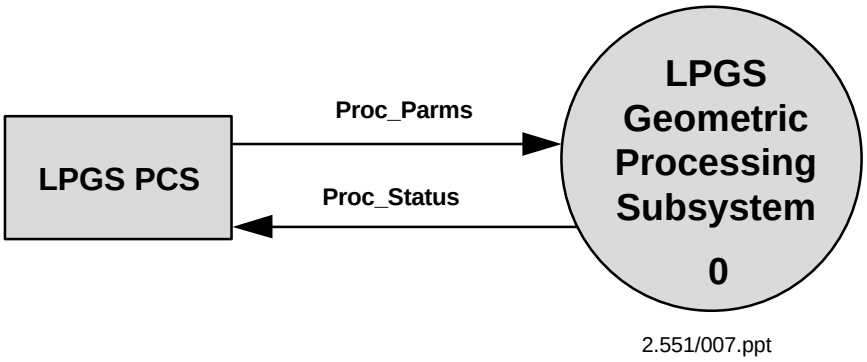


Figure 3-4. GPS Context Diagram

The GPS produces L1G images that are stored in Image_Data store and metadata that are stored in the Ancillary data store before distribution to the ECS. While the L1G processing is being performed, status information is created and transmitted to the PCS.

3.4.3 Functional Description

The primary function of the GPS—performing L1G processing—is described below.

3.4.3.1 Perform L1G Processing

The Perform L1G Processing function extracts information from received processing parameters to perform geometric correction of L1R images. The GPS extracts information from the processing parameters that identify the resampling techniques, grid cell size, map projection, and orientation requested by the user for generating the L1G image. The GPS generates a resampling grid based on the user-selectable grid cell size that can be from 15 to 60 meters. Based on the user-requested resampling technique—nearest neighbor, cubic convolution, or modulation transfer function (MTF) compensation, the GPS applies the technique to recreate the image within the grid. A sophisticated satellite geometric correction model, created from the library of algorithms available to the GPS, is used to perform systematic correction that generates the image according to the desired map projection and orientation.

3.4.4 Data

This section describes the data flows that appear in Figure 3-4 and the data stores that support the GPS.

- **Ancillary**—All datasets needed for processing other than image data, calibration parameter file, and reports
- **Image_Data**—L0R image, L1R image or L1G image
- **Proc_Parms—**Processing parameters entered by users for processing the L1G image such as grid cell size, resampling technique (nearest neighbor, cubic convolution encoding, MTF), map projection, and image orientation. The processing parameters also identify the L1R image and ancillary data used to perform the geometric correction
- **Proc_Status**—Status of processing, which can include percentage of image processed, stage of processing (resampling grid generated, resampling technique applied, geometric correction model applied) and other states

3.4.5 Subsystem Hardware

The GPS executes on the L1 processing HWCI.

3.4.6 Subsystem Software

The GPS software includes custom-developed application code that is also used by the IAS Process Geometry subsystem. The Oracle DBMS is used to access data contained in the Image_Data, Ancillary, and Cal_Parm_File data stores.

3.5 Quality Assessment Subsystem

The QAS provides the functionality required to generate and assemble postproduction information about image artifacts and effects that were not corrected and to produce a summary of the processed image quality.

3.5.1 Requirements Allocation

The complete mapping of LPGS system requirements to subsystems, including the QAS, is provided in Appendix A.

3.5.2 Interfaces

Figure 3-5 illustrates the system context and external interfaces of the QAS. The QAS extracts the L1R and L1G images from the Image_Data store for analysis. The QAS uses ancillary data from the Ancillary data store, L0R_QC_Stats, characterization results from the Char_Results store, and the calibration parameter file to determine whether the image contains artifacts or other effects that have not or could not be corrected. The QAS provides a summary of the quality of the image processing, including information about thresholds applied during processing to the DMS. The QAS begins QAs and performs checks as indicated by Proc_Parms received from PCS. The QAS provides processing status to PCS by Proc_Status.

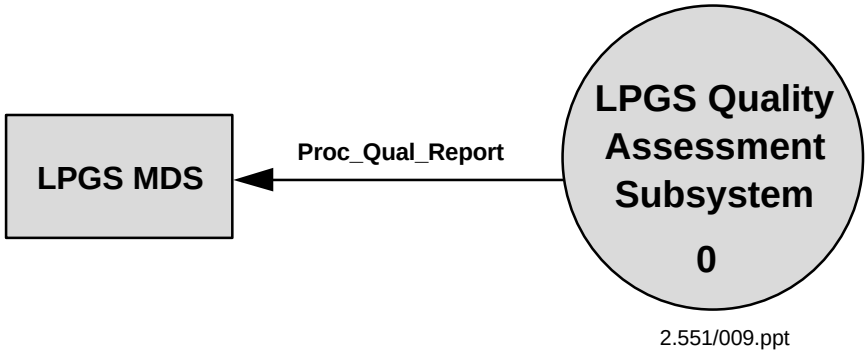


Figure 3-5. QAS Context Diagram

3.5.3 Functional Description

The primary functions of the QAS are described in the following subsections.

3.5.3.1 Assess Quality of L1 Image

The Assess Quality of L1 Image function is automatically initiated when processing parameters from the PCS indicates that radiometric or geometric (if requested) correction has been completed. This QA is performed after each type of correction has been made on an image. This function initially analyzes L0R quality control statistics to identify artifacts and effects in the L0R image that have had an impact on L1 image quality. This function then extracts the L1 image, characterization results including histogram analysis, and the calibration parameter file from the database to identify the location of artifacts and effects the image contains. The function then analyzes processing parameters and status to identify where corrections were made, or not made, and where processing values exceeded or approached specified levels. When processing parameters contain settings that specify that visual inspection of the image is required or that

quality thresholds are exceeded, the function provides an interface to COTS software for displaying the L1 image. The quality analyst can perform a visual inspection of the image, document information obtained from visual analysis of image quality, and note areas in which artifacts or effects not characterized, such as random noise, occur. Processing quality information is made available to the Format Processing Quality Information function for assembly.

3.5.3.2 Format Processing Quality Information

The Format Processing Quality Information function prepares a formatted summary of the quality of the processed image. It receives the information about the location of artifacts and effects that were characterized and corrected or were characterized and not corrected, threshold values contained in processing parameters, actual values attained during processing, and analyst notes. When visual QA is performed, operators may annotate and provide information that is added to the quality report. The Format Processing Quality Information function transmits the processing quality report to the DMS. Quality assessment information is also provided to PCS in the Proc_Status data.

3.5.4 Data

This section describes the data flows that appear in Figure 3-5 and the data stores that support the QAS.

- **Ancillary**—See GPS
- **Cal_Parm_File**—Calibration parameters file
- **Char_Results**—See RPS
- **Image_Data**—See GPS
- **L0R_QC_Stats**—Statistics about the L0R image produced from DMS analysis of raw L0R image quality
- **Proc_Parms**—See GPS
- **Proc_Qual_Report**—A formatted report containing the location and description of artifacts and effects that were characterized and corrected, location and description of artifacts and effects that were characterized and not corrected, processing threshold values, processing values attained, and analyst notes
- **Proc_Stats**—See GPS

3.5.5 Subsystem Hardware

The QAS is hosted and executes on the Quality Assessment/Anomaly Resolution HWCI. The QAS uses one of the display workstations in the HWCI to perform visual inspection of L1 images.

3.5.6 Subsystem Software

The QAS software includes custom-developed application code that is also used by the IAS evaluation and analysis function. COTS application software for displaying images in HDF-EOS format is used when performing visual inspection of the L1 images.

3.6 Anomaly Analysis Subsystem

The AAS provides the functionality required to analyze L1 images and associated postproduction information about image artifacts and effects to resolve image production anomalies.

3.6.1 Requirements Allocation

The complete mapping of LPGS system requirements to subsystems, including the AAS, is provided in Appendix A.

3.6.2 Interfaces

Figure 3-6 illustrates the system context and external interfaces of the AAS. The AAS extracts the L1R and L1G images to be analyzed from the Image_Data store. If still available online, the AAS uses ancillary data from the Ancillary data store, Char_Results from the Char_Results store, and the calibration parameter file to analyze image effects and artifacts that might have caused the image anomaly. System diagnostics and commands may be run to provide information about the status of hardware and custom and COTS software. The AAS provides a summary of the anomaly analysis to the DMS.

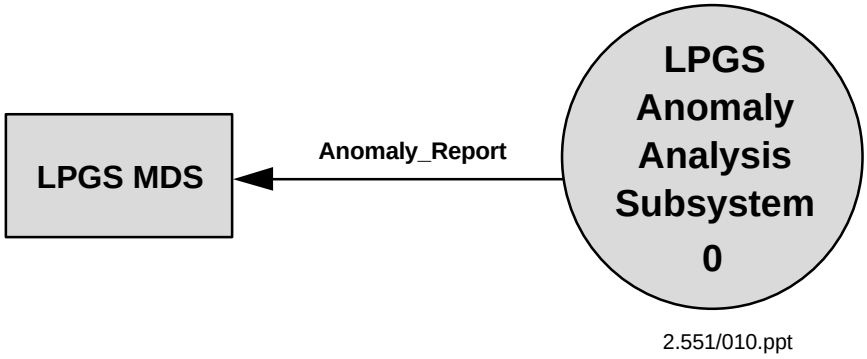


Figure 3-6. AAS Context Diagram

3.6.3 Functional Description

The primary functions of the AAS are described in the following subsections.

3.6.3.1 Analyze Anomalies Detected

The Analyze Anomalies Detected function is manually initiated when processing quality information from the QAS is unacceptable or when the PCS receives a trouble ticket from the ECS. The Analyze Anomalies Detected function provides a display interface that searches for and identifies all data, image, and ancillary information available online for analysis. This function extracts the L1 image from the Image_Data store and extracts the associated ancillary and characterization results data, if still available online, by using information entered by the anomaly analyst. This function provides an interface to COTS software for display and analysis of the image. The function provides an interface for analyzing processing parameters and status to identify where corrections were made or not made and where processing values exceeded or approached specified levels. The anomaly analyst can document information obtained from visual and statistical analysis of image quality, noting information about the anomaly. Anomaly information is made available to the Format Anomaly Report function for assembly.

3.6.3.2 Format Anomaly Report

The Format Anomaly Report function prepares a formatted report of the analysis and resolution of image anomalies, using information and notes generated by and received from the Analyze Anomalies Detected function. The Format Anomaly Report function transmits the formatted anomaly report to the DMS.

3.6.4 Data

This section describes the data flows that appear in Figure 3-6 and the data stores that support the AAS.

- **Ancillary**—See GPS
- **Anomaly_Report**—A free-text report with formatted header information that contains the location and description of anomalies identified in the L1 image; the report also includes a recommendation for either reprocessing with identified parameters or forwarding the problem description to the DHF
- **Cal_Parm_File**—See QAS
- **Char_Results**—See RPS
- **Image_Data**—See GPS
- **Proc_Parms**—See GPS
- **Proc_Stats**—See GPS

3.6.5 Subsystem Hardware

The AAS is hosted and executes on the Quality Assessment/Anomaly Resolution HWCI. The AAS uses one of the display workstations in the HWCI for performing visual analysis of L1 images.

3.6.6 Subsystem Software

The AAS software includes custom-developed application code that is also used by the IAS evaluation and analysis function. COTS application software for displaying images in HDF-EOS, GeoTIFF, or FAST format is used for performing visual inspection of the L1 images.

Section 4. System Support Software

This section specifies the system support software included in the LPGS system design. Section 4.1 describes the operating system and device interface software specified for the LPGS system design. Section 4.2 describes COTS application software specified for the LPGS system design.

4.1 LPGS System Software

LPGS system software includes the IRIX operating system, device drivers, and RAID software.

4.1.1 IRIX Operating System

The software architecture includes a version of the UNIX operating system both because UNIX provides an open system that enhances application portability and because a wide selection of UNIX-based commercial applications are available.

The IRIX operating system has been selected for use on the L1 processing and QA HWCI platforms. The selection of IRIX was driven wholly by the selection of Silicon Graphics, Inc. (SGI) servers as LPGS processing hosts. The decision to use IRIX is confirmed by the use of IRIX on the Landsat Processing System (LPS). Since the decision to use IRIX in LPS, SGI has released a new version (6.2) that incorporates a 64-bit architecture. The use of 64-bit technology has allowed SGI to overcome the 2 GB maximum file size limitations cited in the LPS system design specification (Applicable Document 7).

4.1.2 Add-On Device Driver Support

Devices to be added to any of the platforms in the network require device driver software. For standard devices manufactured by the platform manufacturer, these drivers are generally bundled in the operating system. For third-party devices, the drivers are generally included with the device.

4.1.3 RAID Device Interface

LPGS systems software includes RAID device drivers that implement the interface between the Production Control HWCI platform and the storage on the platform. The software for this function is a software product that implements RAID technology without needing special hardware.

4.2 LPGS COTS Software

LPGS COTS software includes the Oracle DBMS, the NCSA HDF software package, GeoTIFF support software, FAST support software, job scheduling software, and the IDL image display and analysis software.

4.2.1 Oracle DBMS

Oracle is an RDBMS. The decision to specify Oracle as the LPGS DBMS was based on the results of a comparison of databases performed by the Pacor II project in 1992. That comparison's findings remain valid.

Oracle provides standard management services for information stored as a set of relations (tables). It also manages the storage of views, rules, triggers, constraints, and procedures within a database. Standard database management features include transaction-based commit and rollback, two-phase commit for distributed databases, journaling and checkpointing, and database consistency point recovery after catastrophic system failures. It includes [optional] modules for forms-based user interface, report generation, stored procedure definition, and C language API.

Oracle uses a Structured Query Language (SQL)-based data definition and manipulation language. Oracle allows the creator to specify not only the relational structure of a table but also the format and disk area in which it is stored. Oracle allows the definition of multiple views of tables in the database and supports full query and limited modification capabilities of underlying tables through the view. Oracle allows the definition of indexes of up to 16 attributes. Oracle's clustering ability allows the storage of related tables interleaved in the same disk area. Oracle allows the creation of snapshots that locally store the results of a query over tables in a remote database as well as the definition of an automatic periodic refresh interval to maintain the snapshot's currency. Oracle allows the definition and initialization of automatic sequence number attributes attached to rows of a table.

Oracle includes a cost-based query optimizer. To improve performance further, Oracle supports multithreaded servers and automatically determines when queries can be shared between users. Oracle uses configurable read-ahead and write-behind threads.

Oracle includes both line-oriented and forms-based SQL user interfaces for data definition, data manipulation, and database administration. Database access is controllable by passwords and access permissions. PL/SQL is Oracle's procedural language with embedded SQL; it can be used to define stored procedures. Oracle includes a C precompiler and runtime libraries that provide an embedded SQL API.

Oracle includes standard database administration utilities including save/restore, data import/export, system configuration, and access permission and system privilege control. Access permission and privilege granularity is at the table and operation level. Oracle allows the definition of roles, a set of system privileges, and data access privileges on database objects that may be granted/revoked as a unit to a user. Oracle's auditing capabilities allow the generation of access histories for system tuning.

A detailed analysis of how Oracle will be used in conjunction with other LPGS support software will be performed during the subsystem requirements and design phase. The LPGS implementation may use Oracle services as follows:

- Manage LPGS quality and accounting information and set-up tables
- Perform operator update of LPGS set-up tables through Oracle's user interface

- Create LPGS quality and accounting data reports
- Retrieve execution parameters from the database and insert quality and accounting information

4.2.2 NCSA HDF

NCSA HDF is a collection of runtime libraries and utilities that support creation and manipulation of files in the HDF standard. The file format standard, runtime libraries, and utilities were developed by NCSA to allow data sharing through files in a standard, flexible, and machine-independent format. HDF format has been adopted as a standard for Earth sciences files stored in the EOSDIS, of which the LP Distributed Active Archive Center (DAAC) is a member. HDF format is therefore required for L0R files to be transferred to the LP DAAC (see Applicable Document 5).

LPGS applications software linked with HDF runtime libraries create L0R files in HDF format. LPGS operators may use HDF utilities to view and edit HDF files directly.

4.2.3 GeoTIFF Support Software

GeoTIFF is a standard for the storage of geographic raster images. The standard was developed jointly by the Jet Propulsion Laboratory, the United States Geological Survey, Spot Image Corporation, and a number of other commercial entities, with input from over 140 interested individuals. GeoTIFF is based on the tagged image file format (TIFF) standard with special extensions to support the display of geographical images. The LPGS requirements specify GeoTIFF as one of the output formats for distribution. Because a large number of COTS software vendors supply GeoTIFF as part of their solution, these products will be looked at for potential integration in the LPGS to support the translation of output products to GeoTIFF format, as well as the visual display of GeoTIFF format images.

4.2.4 FAST Support Software

FAST is a format currently used by EOSAT for distribution of image products. FAST format B, used for Landsat Thematic Mapper products, contains a header file, image files for each band, and a trailer file that contains ephemeris information used to compute the approximate spacecraft position. The LPGS requirements include FAST as one of the output formats for distribution. COTS software vendors will be assessed for potential integration into the LPGS to support the translation of output products to FAST format as well as ingest and display of FAST format images.

4.2.5 Job Scheduling Software

To reduce the development cost and time and to reduce risks in operations, the LPGS implementation will use a commercial job scheduling package, such as Platinum Technology's Autosys. Software in this category provides the capability to start processing automatically, based on various events, including

- Data arrival
- Processing completion status
- Time of day
- Resource availability

4.2.6 Image Display and Analysis Software

The LPGS has selected the same COTS image display and analysis tools for its analysis workstations as the IAS. The IDL from Research Systems, Inc., and ENVI interface products will be used. IDL is a software package for data analysis, visualization, and application development. IDL's features include image processing, interactive 2D and 3D graphics, insightful volume visualization, a high-level programming language, integrated mathematics and statistics, flexible data input/output, a cross-platform GUI toolkit, and program linking tools.

The features of IDL include

- Visualization
- Image and signal processing
- Mathematics and statistics
- Data formats
- Development tools

Section 5. Operations Design

This section provides an operational overview of the system and details on the LPGS operations design. Examining system operations provides information on relationships of events in time and operator interfaces. Investigating system operations provides an understanding of the sequence of events, concurrency, and workload. This section describes the LPGS normal and contingency operational scenarios.

5.1 LPGS Operational Overview

The LPGS receives L1 product generation requests and distributes generated products to customers through the ECS at the EDC on a first-ordered, first-processed basis. The LPGS is the responsibility of the ESDIS Project and is to be installed at the EDC DAAC to provide product generation and distribution support for a Landsat 7 minimum mission life of 5 years. Based on customer requests, the LPGS produces L1 data products in electronic format corresponding to a WRS scene or partial ETM+ subintervals. The LPGS can produce a daily volume of 25 WRS scenes of L1G, radiometrically corrected and digitally resampled for geometric correction and geographic registration. LPGS can create digital images projected to different coordinate reference systems for any subset of the eight spectral channels collected by the ETM+ instrument or in different output formats according to other options specified in the customer's request. The LPGS requests L0R data from the ECS and applies appended calibration parameter, PCD, and MSCD files in producing L1 data products. The digital image created by the LPGS is provided, along with metadata and processing status and quality information, to the ECS. The ECS distributes the entire L1 product, including the calibration parameter file, consensus PCD, and consensus MSCD, where applicable, to the customer.

5.2 Operational Concepts

LPGS operations have been allocated to three different phases of activities: preproduction, production, and postproduction. The preproduction phase includes production planning, scheduled system maintenance, algorithm integration, and product request processing in preparation for L1 data production. The production phase includes the actual processing of L0R data to create systematically corrected digital images. This phase includes generation of data and production QAs that can be visually inspected or automatically monitored during various stages of product generation. The postproduction phase includes generation of product and production quality assessment and characterization results reports and distribution of L1 images, associated data, and accounting information. All phases include both automatic and manual activities.

5.3 Nominal Operations

This section describes major operational activities performed by the LPGS in nominal mode for the three different operational phases. Figure 5-1 shows the interaction of the various LPGS subsystems as they perform nominal LPGS processing.

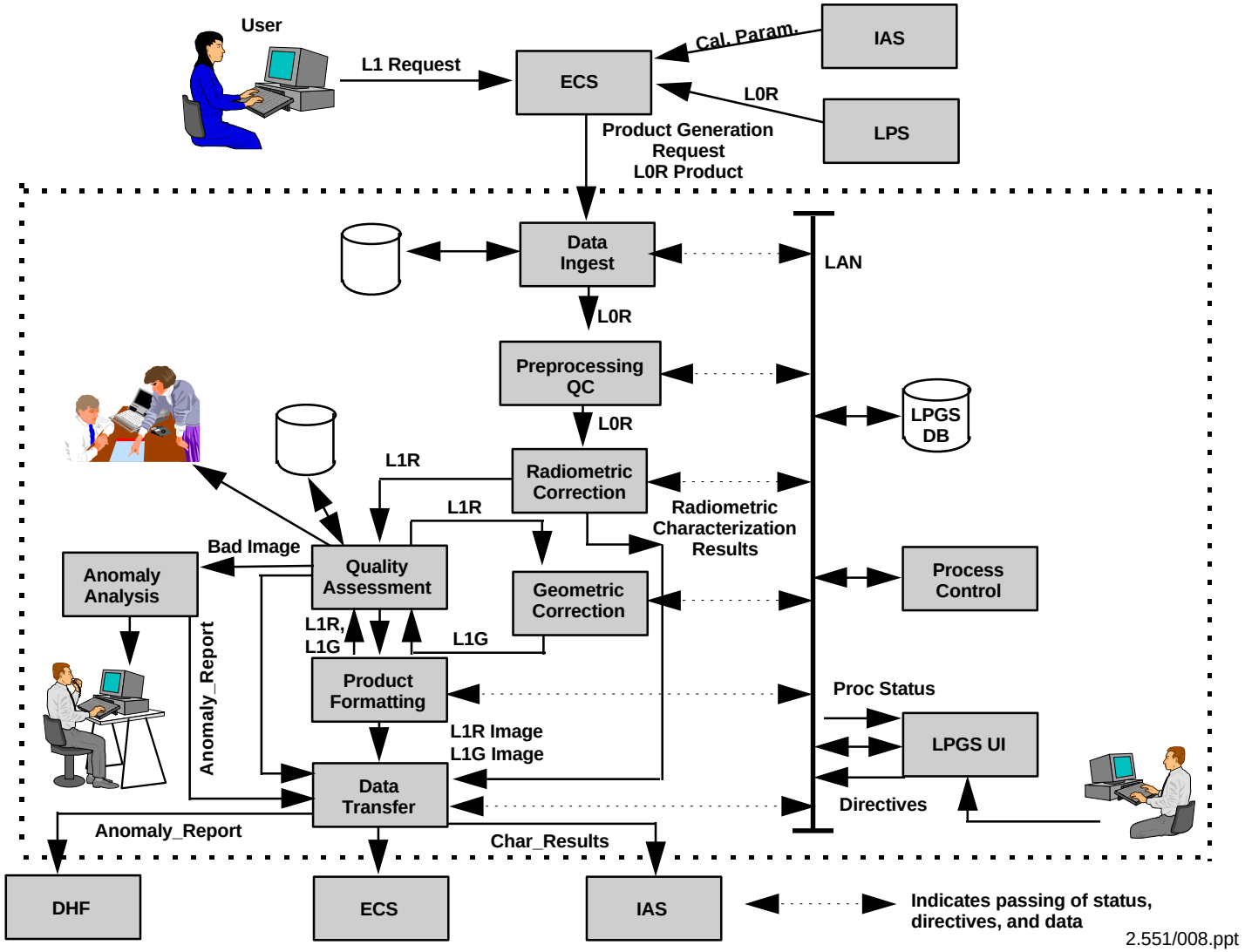


Figure 5-1. LPGS Processing Flow

5.3.1 Preproduction Phase

The preproduction phase encompasses four main activities, discussed in the following subsections.

5.3.1.1 Product Request Processing

LPGS automatically receives and begins processing L1 product generation requests. The ECS transmits requests to the LPGS, and the customer-specified processing parameters, ECS-applied request ID, and required L0R data are identified and extracted without operator intervention. These extracted data are used to create a work order, which is queued for processing on a first-in, first-processed basis. After a work order is created, status is generated and kept on the work order.

5.3.1.2 Production Planning

Production planners can manually review the current production queue for a given day. Each day, the LPGS system automatically distributes the status of the production queue to the ECS at the designated time entered into the system. Processing status for an individual work order or L1 product request is also provided automatically on receipt of a production status request from the ECS. L1 processing is performed on a FIFO basis; however, the production planners can promote work orders in the processing queue as needed.

Production planning includes requesting L0R data from the ECS based on information contained in the work order. The LPGS receives notification from the ECS that the L0R data are available for transfer. The LPGS communicates with the ECS to coordinate transfer of the L0R data from a designated staging area and to notify the ECS that the data have been successfully received. When L0R data have been successfully received, production status is automatically updated to indicate that all required data are available and that processing may commence. System operators can review production status and manually set image processing parameters and intermediate output options for a specific work order.

5.3.1.3 Scheduled System Maintenance

Scheduled system maintenance, including backups, is performed automatically according to preentered operator directives. Maintenance activities are conducted in off-shift hours to avoid impact on production. System storage maintenance is also performed automatically. Each day, at a time designated and entered into the system by the subsystem operator, the LPGS automatically assesses system storage capacity. The LPGS maintains a minimum available storage volume for temporarily retained data. When the available. LPGS temporary storage approaches the minimum, the LPGS purges from temporary storage L0R data that have expired or L1 data that have been successfully retrieved by the ECS. System operators may select datasets and specify that they should be permanently saved and not purged. The LPGS can display, as a monitoring function or at operator directive, storage statistics to verify that sufficient storage is available to accommodate the receipt of data to be processed for that day.

5.3.1.4 Algorithm Integration

Algorithm updates identified by software developers or IAS analysts are proposed to the LPGS Project Configuration Management Board (PCMB). The algorithm is integrated into the test baseline and tested in a model of the image processing subsystem in the development, test, and maintenance subsystem. After PCMB review and approval of the algorithm update, the updated algorithm is scheduled for integration into the production baseline. Modification of the production baseline is scheduled for off-peak hours and includes duplicating sample image processing performed in the test environment.

5.3.2 Production Phase

The production phase encompasses two main activities, discussed in the following subsections.

5.3.2.1 L1 Product Generation

When all needed data are available and processing resources are available, image processing is initiated. L0R products, including the appended calibration parameter file, PCD, and MSCD, are accessed from temporary storage for processing. Before initiation of the processing flow, the system operator can specify system parameters that cause digital images and characterization statistics to be saved offline during specified intervals within the radiometric or geometric correction processing flow.

5.3.2.2 Processing Quality Assessment

During L1 processing, the LPGS automatically collects quality and assessment information according to default and operator-specified directives. The processing quality information includes data on processing accuracy and corrections applied. Nominally, processing quality is checked automatically by the LPGS, using default or operator-specified thresholds as a standard. The quality analyst may also manually check processing data and visually inspect images to verify characterizations performed and corrections applied. Images that do not meet quality inspection standards can be reprocessed or further analyzed during the postproduction phase.

5.3.3 Postproduction Phase

The postproduction phase encompasses three main activities, discussed in the following subsections.

5.3.3.1 Report Generation

Postproduction analysis includes generation of reports from characterization results and processing quality information collected during the production phase. The LPGS also generates reports that contain accounting information, including the number of L1 product generation requests processed and L1 images produced. Characterization results reports are periodically transmitted to the IAS.

5.3.3.2 L1 Data Distribution

After completion of processing and quality report generation, L1 image data and appended processing statistics and quality information are transferred to the temporary storage area and a designated staging area in preparation for transmission to the ECS. The LPGS notifies the ECS of the availability of the L1 image by using the product request IDs and established message protocol. After the ECS has confirmed receipt of the L1 image and production quality information, the data are marked for purging from the staging area. The LPGS then closes the work order and updates the work order accounting information on periodic receipt of accounting information from the ECS.

5.3.3.3 Anomaly Resolution

When anomalies are found during production and before distribution of images to the ECS, anomaly analysts initially examine production quality reports to determine if the source of the anomaly is within the LPGS image processing system. If reprocessing the image does not resolve the anomaly, then options specified in the L1 product request and the processed L0R images are analyzed to identify a possible cause. A benchmark or calibration scene may be processed by the LPGS system operators to verify whether the LPGS image processing software has problems. If no anomalies are found in the L1 product generation request, L0R image, or L1 production process, then an anomaly report is forwarded to the DHF for analysis. Anomaly analysts also investigate anomalies found by customers in received L1 products in response to ECS-generated trouble tickets. LPGS anomaly analysts examine the L1 data to verify that products were properly distributed to the ECS. The LPGS may then reprocess the image to determine whether the product is consistent with products received by the customer. If the reprocessed product is consistent with the anomalous product received by the customer, then the LPGS production analysts examine production quality reports to assess whether thresholds were approached. If no anomalies are found in the L1 product generation request, L0R image, or L1 production process, the available information about the anomaly is forwarded to the DHF for analysis. A trouble ticket is generated and transmitted to ECS. Anomaly resolution, in turn, can be triggered when the receives an ECS trouble ticket.

5.4 Contingency Operations

This section describes major operational activities performed by the LPGS in response to system anomalies and failures, both internal and external to the LPGS.

5.4.1 LPGS Failure

A failure of the LPGS can be caused by failure of any LPGS subsystem that provides operational support of L1 image production, with the exception of the billing, accounting, and management and the development, test, and maintenance subsystems. LPGS failure can be detected by analyzing error messages received during scheduling, image processing, or image analysis. The LPGS system operators notify EDC DAAC user services and production support offices and IAS operators of the failure, either electronically or through a contingency medium or method. Operations procedures are implemented to isolate the failure within a specific LPGS subsystem.

Operations procedures are followed to resolve and recover from the failure. As information becomes available, the ECS and IAS may be provided with an estimate of the impact on production operations and the estimated time of return to full or partial operations. If the production planning subsystem is available, processing estimates may be made, and the DAAC can be provided with a tentative modification to the latest production status. After a failure is resolved, updated production status is provided to the ECS. L0R data that have been lost or corrupted before processing are again requested from the ECS and reprocessed according to the modified production status. L1 data that have been lost or corrupted before distribution to the ECS are reprocessed and then distributed.

5.4.2 Failure of Communications Link to the ECS

In the event of failure of communications links between the LPGS and ECS, the ECS system operator is notified of the failure by voice communications. Operations procedures are followed to determine which communication link failed. The LPGS distribution and message transmission subsystem is configured to discontinue transmission of L1 products and L0R data requests to the ECS. The LPGS production schedule continues to be followed, as much as possible, with continued processing of L0R data in working storage. If production can no longer continue because all online L0R data have been processed, then alternate methods can be used, if available, to request and retrieve L0R data. L1 data that have been produced are held in temporary storage until communications have been reestablished and verified. When communications have been reestablished, the LPGS follows operations procedures to perform an accounting with the ECS to identify data lost because of failure of the communication link between the LPGS and the ECS.

Appendix A. LPGS Requirements Allocation Matrix

REQ #	Requirement Summary	PCS	DMS	RPS	GPS	QAS	AAS
3.1	System-Level Requirements						
3.1.1	The LPGS shall nominally generate L1 data products on a first-ordered, first-processed (FIFO) basis.	X	X	X	X	X	
3.1.2	The LPGS shall provide the capability to move a level 1 image processing work order within the FIFO queues according to operator direction.	X					
3.1.3	Deleted						
3.1.4	Deleted						
3.1.5	The LPGS shall provide the capability to generate and report LPGS error messages.	X	X	X	X	X	X
3.1.6	The LPGS shall provide an interactive capability to facilitate detection and correction of abnormal system conditions.	X	X	X	X	X	X
3.1.7	The LPGS shall provide the capability to isolate system faults.	X					
3.1.8	The LPGS shall provide the capability to recover from system faults.	X					
3.1.9	The LPGS shall provide the capability to test LPGS functions and external interfaces.	X	X	X	X	X	X
3.1.10	The LPGS shall provide the capability to support attended operations 24 hours a day, 7 days a week, on a continuous basis.	X	X	X	X	X	X
3.1.11	The LPGS shall provide the capability to support unattended, automatic processing 16 hours a day, 7 days a week, on a continuous basis.	X	X	X	X	X	
3.1.12	The LPGS shall provide the capability to support Landsat 7 operations for a minimum mission life of 5 years.	X	X	X	X	X	X
3.1.13	The LPGS shall provide the capability to execute diagnostic tests for verifying proper operation of system capabilities and components.	X	X	X	X	X	X
3.1.14	The LPGS shall provide the capability to support end-to-end testing of Level 1 processing functions.	X	X	X	X	X	X
3.1.15	The LPGS shall provide the capability to control LPGS operations.	X					
3.1.16	The LPGS shall provide the capability to monitor LPGS operations.	X					
3.1.17	The LPGS shall provide the capability to reconfigure LPGS system resources.	X					
3.1.18	Provide the capability to support software upgrades while supporting normal operations.	X	X	X	X	X	X
3.1.19	The LPGS shall be capable of making all software and databases used in operations accessible to ECS for archiving.		X				
3.1.20	The LPGS design shall be scaleable to allow for future growth in processing capability.	X	X	X	X	X	X

REQ #	Requirement Summary	PCS	DMS	RPS	GPS	QAS	AAS
3.1.21	The LPGS shall be able to generate level 1 digital images corresponding to either heritage world-wide reference system (WRS) scenes or to a partial ETM+ subinterval up to an area equivalent to three WRS scenes.				X	X	
3.1.22	The LPGS shall be capable of recovering from failures and aborts in a controlled manner.	X	X	X	X	X	X
3.2	External Interface Requirements						
3.2.1	LPGS shall interface with the ECS to receive the following:		X				
3.2.1.1	L0R files (includes associated PCD, MSCD, and calibration parameter files)		X				
3.2.1.2	Level 1 image processing requests		X				
3.2.1.3	Data availability notification		X				
3.2.1.4	Production status requests		X				
3.2.1.5	Product cancellation requests		X				
3.2.1.6	Product problem report (trouble ticket)		X				
3.2.2	LPGS shall interface with the ECS to coordinate transfer of		X				
3.2.2.1	LPGS L1 digital images		X				
3.2.2.2	Processing status		X				
3.2.2.3	Production quality and accounting information		X				
3.2.2.4	L1 processing statistics		X				
3.2.2.5	L1 metadata		X				
3.2.2.6	PCD file (consensus)		X				
3.2.2.7	MSCD file (consensus)		X				
3.2.2.8	IC data file		X				
3.2.2.9	CPF		X				
3.2.2.10	Geolocation table		X				
3.2.3	The LPGS shall interface with the Image Assessment System (IAS) to provide Level 1 radiometric characterization data.		X	X			
3.2.4	LPGS shall interface with the DHF to provide L1 processing anomaly reports.		X			X	X
3.3	Functional Requirements						
3.3.1	Retrieve L0R files.						
3.3.1.1	The LPGS shall provide the capability to receive L0R data inputs from the ECS. This data shall include the following items:		X				
3.3.1.1.1	Level 1 image processing request that includes the following:						
3.3.1.1.1a	Selected coordinate reference system for map projection		X				
3.3.1.1.1b	Requested orientation (Nominal Path or North Up)		X				
3.3.1.1.1c	Variable grid cell size selection		X				
3.3.1.1.1d	Output format selection		X				
3.3.1.1.1e	Resampling filter		X				
3.3.1.1.1f	Selected bands		X				
3.3.1.1.1g	Selected scene or subinterval identification		X				
3.3.1.1.1h	L1R or L1G image processing selection		X				

REQ #	Requirement Summary	PCS	DMS	RPS	GPS	QAS	AAS
3.3.1.1.1i	Geographic area		X				
3.3.1.1.1j	WRS (path/row) scene identifier		X				
3.3.1.1.1k	Internal calibrator (IC) or calibration parameter pile (CPF) (default = CPF)		X				
3.3.1.1.2	Data availability notification specifying the location of associated L0R product files ready for retrieval		X				
3.3.1.1.3	L0R product files (includes L0R image data, PCD, MSCD, and associated calibration files), internal calibrator, and calibration parameter		X				
3.3.1.1.4	Production status request		X				
3.3.1.1.5	Product cancellation request		X				
3.3.1.1.6	Product problem report (trouble ticket)		X				
3.3.1.2	LPGS shall provide the capability to create and send L0R product requests to the ECS.	X	X				
3.3.1.3	LPGS shall coordinate resolution of data transfer problems with any L0R product file with the ECS.		X				
3.3.1.3.1	LPGS shall be able to detect data transfer problems.		X				
3.3.1.3.2	LPGS shall be able to re-retrieve data.		X				
3.3.2	The LPGS shall be able to extract and process Landsat 7 ETM+ Earth image data from the L0R Earth image data file to produce radiometrically corrected L1R digital images.		X	X			
3.3.2.1	The LPGS shall be able to extract and process attitude, and ephemeris data from the L0R payload correction data (PCD) files.		X	X			
3.3.2.2	The LPGS shall be able to extract parameters from the L0R internal calibrator or calibration parameter file for use in L1R and L1G processing.		X	X			
3.3.2.3	The LPGS shall be able to generate gains and biases from either the internal calibrator data or from the calibration parameter file. The default shall be the calibration parameter file.			X			
3.3.2.4	The LPGS shall be able to extract and process mirror scan correction coefficients from the L0R MSCD file to determine scan line quality.			X			
3.3.2.5	The LPGS shall be capable of detecting the following image artifacts:			X			
3.3.2.5.1	Striping			X			
3.3.2.5.2	Banding			X			
3.3.2.5.3	Coherent noise			X			
3.3.2.5.4	Deleted			X			
3.3.2.5.5	Scan-correlated shift			X			
3.3.2.5.6	Saturated detectors			X			
3.3.2.5.7	Dropped scan lines			X			
3.3.2.6	The LPGS shall be capable of characterizing the following image artifacts:						
3.3.2.6.1	Striping			X			
3.3.2.6.2	Banding			X			

REQ #	Requirement Summary	PCS	DMS	RPS	GPS	QAS	AAS
3.3.2.6.3	Coherent noise			X			
3.3.2.6.4	Deleted						
3.3.2.6.5	Deleted						
3.3.2.6.6	Saturated detectors			X			
3.3.2.6.7	Dropped scan lines			X			
3.3.2.7	The LPGS shall be capable of applying compensation for the following image artifacts:						
3.3.2.7.1	Striping			X			
3.3.2.7.2	Banding			X			
3.3.2.7.3	Coherent noise			X			
3.3.2.7.4	Memory effect			X			
3.3.2.7.5	Scan correlated shift			X			
3.3.2.7.6	Inoperable detectors			X			
3.3.2.7.7	Saturated detectors			X			
3.3.2.7.8	Dropped scan lines			X			
3.3.2.8	The LPGS shall be capable of applying compensation for gain changes within a requested L1 scene or subinterval as identified in the Level 0R metadata.			X			
3.3.2.9	The LPGS shall be capable of producing L1R data from L0R data for both the ascending and descending portions of the Landsat 7 orbit.			X			
3.3.2.10	The LPGS shall be able to produce L1R digital images for any combination of the eight spectral channels.			X			
3.3.2.11	The LPGS shall assemble and append to the L1R digital images all of the applicable metadata and quality and accounting data gathered in the construction of the L1R digital image. The complete L1R digital image package contains the following data elements as a minimum:		X				
3.3.2.11.1	Level 1R digital image (all requested bands)		X				
3.3.2.11.2	L1 metadata file		X				
3.3.2.11.3	Quality and accounting file		X				
3.3.3	The LPGS shall be able to extract and process Landsat 7 ETM+ Earth image data from the L1R Earth image data files to produce systematically corrected L1G digital images.				X		
3.3.3.1	The LPGS shall have the capability to resample L1R digital images and apply the following map projections:				X		
3.3.3.1.1	Space oblique Mercator				X		
3.3.3.1.2	Universal Transverse Mercator (UTM)				X		
3.3.3.1.3	Lambert conformal conic				X		
3.3.3.1.4	Transverse Mercator				X		
3.3.3.1.5	Oblique Mercator				X		
3.3.3.1.6	Polyconic				X		
3.3.3.1.7	Polar stereographic				X		

REQ #	Requirement Summary	PCS	DMS	RPS	GPS	QAS	AAS
3.3.3.2	The LPGS shall support the following compensation resampling methods:						
3.3.3.2.1	Nearest neighbor				X		
3.3.3.2.2	Cubic convolution				X		
3.3.3.2.3	Modulation Transfer Function (MTF)				X		
3.3.3.3	The LPGS shall have the capability to produce L1G digital images with the following grid cell characteristics:						
3.3.3.3.1	Grid cell size is variable from 15M to 60M in 0.001M increments				X		
3.3.3.3.2	Grid cell size is independently variable between spectral bands				X		
3.3.3.4	The LPGS shall produce L1G digital images that are spatially continuous between contiguous partial subintervals or WRS scenes.				X		
3.3.3.5	The LPGS shall have the capability to generate L1G digital images oriented by the following:				X		
3.3.3.5.1	Oriented to Nominal Path				X		
3.3.3.5.2	Oriented to North Up				X		
3.3.3.6	The LPGS shall be capable of producing L1G data from L0R data for both the ascending and descending portions of the Landsat 7 orbit.				X		
3.3.3.7	The LPGS shall be able to produce L1G digital images for any combination of the eight spectral channels.				X		
3.3.3.8	The LPGS shall assemble and append to the L1G digital images all of the applicable metadata, quality and accounting data gathered in the construction of the L1G digital image. The complete L1G digital image package contains the following data elements as a minimum:		X				
3.3.3.8.1	Level 1G digital Image (all requested bands)		X				
3.3.3.8.2	L1 metadata file		X				
3.3.3.8.3	Quality and accounting file		X				
3.3.4	Generate L1 metadata file.						
3.3.4.1	The LPGS shall generate ancillary L1R digital image data that describes the contents, processing parameters, and quality indicators of the L1R digital image.		X	X			
3.3.4.2	The LPGS shall generate ancillary L1G digital image that describes the contents, processing parameters, and quality indicators of the L1G digital image.		X		X		
3.3.4.3	The LPGS shall generate and append processing summary indicators specifying the algorithms applied to the Level 1 digital images.		X				
3.3.5	Assess L1 product quality.						
3.3.5.1	The LPGS shall support automatic assessment of L1 digital image quality.					X	

REQ #	Requirement Summary	PCS	DMS	RPS	GPS	QAS	AAS
3.3.5.2	The LPGS shall be able to optionally display any single band of the L1R digital image for visual quality assessment.					X	X
3.3.5.3	The LPGS shall be able to optionally display any single band of the L1G digital image for visual quality assessment					X	X
3.3.5.4	The LPGS shall be able to optionally print a color hardcopy of the display of any band(s) of the L1R digital image for visual quality assessment.					X	X
3.3.5.5	The LPGS shall be able to optionally print a color hardcopy of the display of any band(s) of the L1G digital image for visual quality assessment.					X	X
3.3.6	Transfer L1 file(s).						
3.3.6.1	The LPGS shall be able to output L1 digital images in the following formats:						
3.3.6.1.1	HDF-EOS (L1R and L1G)		X				
3.3.6.1.2	EOSAT FAST-Format (L1G only)		X				
3.3.6.1.3	GeoTIFF (L1G only)		X				
3.3.6.2	The LPGS shall transfer L1 files to ECS per the ECS to LPGS ICD.		X				
3.3.6.3	The LPGS shall provide the capability to display LPGS Level 1 file transfer summary upon operator request.		X				
3.3.6.4	The LPGS shall be able to detect files that have been successfully transferred.		X				
3.3.6.5	The LPGS shall be able to mark successfully transferred files as candidates for deletion from LPGS temporary storage.		X				
3.3.7	Data storage						
3.3.7.1	The LPGS shall be able to provide temporary online storage for the equivalent of 3 days of completed products.		X				
3.3.7.2	The LPGS shall be able retransmit files located in temporary storage.		X				
3.3.7.3	The LPGS shall be able to store Level 1 processing information on line for 90 days.		X				
3.3.7.4	The LPGS shall be able to transfer Level 1 processing information to offline storage after 90 days.		X				
3.3.7.5	The LPGS shall be able to recover, display, and print Level 1 processing information located on offline storage for the life of the mission.	X	X				
3.3.7.6	The LPGS shall be able to provide temporary online storage for up to 25 L0R scene equivalents and associated input files.		X				
3.3.8	Control LPGS operations.						
3.3.8.1	LPGS shall allow the operator to select thresholds for statistics and errors reported by the LPGS.	X					
3.3.8.2	The LPGS shall automatically generate messages and alarms to alert the operator of LPGS results and errors exceeding operator selected thresholds.	X		X	X	X	

REQ #	Requirement Summary	PCS	DMS	RPS	GPS	QAS	AAS
3.3.8.3	The LPGS shall generate intermediate processing summaries on a periodic basis according to operator specification.	X		X	X		
3.3.8.4	The LPGS shall provide an option to display L1 digital image quality status and statistics at operator request.	X				X	X
3.3.8.5	The LPGS shall provide an option to print L1 digital image quality status and statistics at operator request.	X				X	X
3.3.8.6	The LPGS shall provide the capability to manually override the LPGS automated processing functions.	X					
3.3.8.7	The LPGS shall provide the manual capability to cancel Level 1 processing prior to completion of digital image generation.	X					
3.3.8.8	The LPGS shall be able to display and print trouble tickets received from ECS.	X				X	X
4	LPGS Performance Requirements						
4.1	Performance Requirements.						
4.1.1	The LPGS shall be capable of processing a volume of data equivalent to 28 (accounts for 10 percent of LPGS internal reprocessing) standard L0R WRS scenes to Level 1 digital images each day.		X	X	X		
4.1.2	The LPGS shall contribute no greater than .7 percent uncertainty to absolute radiometric accuracy during the generation of L1R and 1G digital images.			X	X		
4.1.3	The LPGS shall contribute circular errors no greater than 1.8 m, 1 sigma, in the production of systematically corrected L1G digital images.				X		
4.1.4	The LPGS shall provide at least 110 percent of the processing throughput capability required to satisfy the worst case processor loading.		X	X	X		
4.1.5	The LPGS shall provide at least 125 percent of the random access memory capacity required to satisfy the worst case memory loading.		X	X	X		
4.1.6	The LPGS shall provide at least 125 percent of the peripheral storage capacity required to satisfy the worst case peripheral storage loading.		X				
4.1.7	Deleted						
4.1.8	The LPGS shall produce Level 1G products that are accurate to within 250 meters cross track and 250 meters along track using geometric calibration information generated by IAS and contained in the associated calibration parameter file.				X		
4.2	External Interface Performance Requirements						
4.2.1	The LPGS shall be able to ingest from ECS a data volume equivalent to 3 WRS scenes' worth of standard L0R data for each Level 1 digital image request.		X				
4.2.2	The LPGS shall have the capability to support the transfer to ECS of the equivalent of a minimum of 25 WRS sized Level 1 digital images per day.		X				

REQ #	Requirement Summary	PCS	DMS	RPS	GPS	QAS	AAS
4.2.3	The LPGS-ECS interface shall provide the capability to transfer to the ECS at least 33 gigabytes of Level 1 output files per day.		X				
4.3	Reliability, maintainability, and availability.						
4.3.1	The LPGS shall provide an operational availability of .96 (TBR).	X	X	X	X	X	X
4.3.2	The LPGS shall support a mean time to restore (MTTR) capability of 4 hours (TBR).	X	X	X	X	X	X
4.4	Security.						
4.3.1	The LPGS shall provide system, network, and operations security according to the ESDIS security policy (Applicable Document 8) and the NASA AIS Handbook (Applicable Document 9).	X	X	X	X	X	X

Appendix B. LPGS Requirements Allocation to Hardware/Software/Operations Matrix

REQ #	Requirement Summary	H/W	S/W	OPS
3.1	System-Level Requirements			
3.1.1	The LPGS shall nominally generate L1 data products on a first-ordered, first-processed (FIFO) basis.	X	X	
3.1.2	The LPGS shall provide the capability to move a Level 1 image processing work order within the FIFO queues according to operator direction.		X	X
3.1.3	Deleted			
3.1.4	Deleted			
3.1.5	The LPGS shall provide the capability to generate and report LPGS error messages.		X	
3.1.6	The LPGS shall provide an interactive capability to facilitate detection and correction of abnormal system conditions.	X	X	X
3.1.7	The LPGS shall provide the capability to isolate system faults.	X	X	X
3.1.8	The LPGS shall provide the capability to recover from system faults.	X	X	X
3.1.9	The LPGS shall provide the capability to test LPGS functions and external interfaces.	X	X	X
3.1.10	The LPGS shall provide the capability to support attended operations 24 hours per day, 7 days per week, on a continuous basis.	X	X	X
3.1.11	The LPGS shall provide the capability to support unattended, automatic processing 16 hours per day, 7 days per week, on a continuous basis.	X	X	X
3.1.12	The LPGS shall provide the capability to support Landsat 7 operations for a minimum mission life of 5 years.	X	X	X
3.1.13	The LPGS shall provide capability to execute diagnostic tests for verifying proper operation of system capabilities and components.	X	X	X
3.1.14	The LPGS shall provide the capability to support end-to-end testing of Level 1 processing functions.	X	X	X
3.1.15	The LPGS shall provide the capability to control LPGS operations.		X	X
3.1.16	The LPGS shall provide the capability to monitor LPGS operations.		X	X
3.1.17	The LPGS shall provide the capability to reconfigure LPGS system resources.	X	X	X
3.1.18	Provide the capability to support software upgrades while supporting normal operations.	X	X	X
3.1.19	The LPGS shall be capable of making all software and databases used in operations accessible to ECS for archiving.	X	X	
3.1.20	The LPGS design shall be scalable to allow for future growth in processing capability.	X	X	

REQ #	Requirement Summary	H/W	S/W	OPS
3.1.21	The LPGS shall be able to generate level 1 digital images corresponding to either heritage world-wide reference system (WRS) scenes or to a partial ETM+ subinterval up to an area equivalent to three WRS scenes.		X	
3.1.22	The LPGS shall be capable of recovering from failures and aborts in a controlled manner.	X	X	
3.2	External Interface Requirements			
3.2.1	LPGS shall interface with the ECS to receive the following:			
3.2.1.1	L0R files (includes associated PCD, MSCD, and calibration parameter files)	X	X	
3.2.1.2	Level 1 image processing requests	X	X	
3.2.1.3	Data availability notification	X	X	
3.2.1.4	Production status requests	X	X	
3.2.1.5	Product cancellation requests	X	X	
3.2.1.6	Product problem report (trouble ticket)	X	X	
3.2.2	LPGS shall interface with the ECS to coordinate transfer of the following:			
3.2.2.1	LPGS L1 digital images	X	X	
3.2.2.2	Processing status	X	X	
3.2.2.3	Production Quality and Accounting information	X	X	
3.2.2.4	L1 Processing statistics	X	X	
3.2.2.5	L1 Metadata	X	X	
3.2.2.6	PCD file (consensus)	X	X	
3.2.2.7	MSCD file (consensus)	X	X	
3.2.2.8	IC data file	X	X	
3.2.2.9	CPF	X	X	
3.2.2.10	Geolocation table	X	X	
3.2.3	The LPGS shall interface with the Image Assessment System (IAS) to provide Level 1 radiometric characterization data.	X	X	
3.2.4	LPGS shall interface with the DHF to provide L1 processing anomaly reports.	X	X	X
3.3	Functional requirements			
3.3.1	Retrieve L0R files.	X	X	
3.3.1.1	The LPGS shall provide the capability to receive L0R data inputs from the ECS. This data shall include the following items:	X	X	
3.3.1.1.1	Level 1 image processing request that includes the following:	X	X	
3.3.1.1.1a	Selected coordinate reference system for map projection	X	X	
3.3.1.1.1b	Requested orientation (Nominal Path or North Up)	X	X	
3.3.1.1.1c	Variable grid cell size selection	X	X	
3.3.1.1.1d	Output format selection	X	X	
3.3.1.1.1e	Resampling filter	X	X	
3.3.1.1.1f	Selected band(s)	X	X	
3.3.1.1.1g	Selected scene or subinterval identification	X	X	

REQ #	Requirement Summary	H/W	S/W	OPS
3.3.1.1.1h	L1R or L1G image processing selection	X	X	
3.3.1.1.1i	Geographic area	X	X	
3.3.1.1.1j	WRS (Path/Row) scene identifier	X	X	
3.3.1.1.1k	Internal calibrator (IC) or calibration parameter file (CPF) (default = CPF)	X	X	
3.3.1.1.2	Data availability notification specifying the location of associated L0R product files ready for retrieval.	X	X	
3.3.1.1.3	L0R product files (includes L0R image data, PCD, MSCD, and associated calibration files), internal calibrator and calibration parameter.	X	X	
3.3.1.1.4	Production status request	X	X	
3.3.1.1.5	Product cancellation request	X	X	
3.3.1.1.6	Product problem report (trouble ticket)	X	X	
3.3.1.2	LPGS shall provide the capability to create and send L0R product requests to the ECS.	X	X	
3.3.1.3	LPGS shall coordinate resolution of data transfer problems with any L0R product file with the ECS.	X	X	X
3.3.1.3.1	LPGS shall be able to detect data transfer problems.		X	
3.3.1.3.2	LPGS shall be able to re-retrieve data.	X	X	
3.3.2	The LPGS shall be able to extract and process Landsat 7 ETM+ Earth image data from the L0R Earth image data file to produce radiometrically corrected L1R digital images.		X	
3.3.2.1	The LPGS shall be able to extract and process attitude, and ephemeris data from the L0R payload correction data (PCD) files.		X	
3.3.2.2	The LPGS shall be able to extract parameters from the L0R internal calibrator or calibration parameter file for use in L1R and L1G processing.		X	
3.3.2.3	The LPGS shall be able to generate gains and biases from either the internal calibrator data or from the calibration parameter file. The default shall be the calibration parameter file.		X	
3.3.2.4	The LPGS shall be able to extract and process mirror scan correction coefficients from the L0R MSCD file to determine scan line quality.		X	
3.3.2.5	The LPGS shall be capable of detecting the following image artifacts:		X	
3.3.2.5.1	Striping		X	
3.3.2.5.2	Banding		X	
3.3.2.5.3	Coherent noise		X	
3.3.2.5.4	Deleted		X	
3.3.2.5.5	Scan-correlated shift		X	
3.3.2.5.6	Saturated detectors		X	
3.3.2.5.7	Dropped scan lines		X	
3.3.2.6	The LPGS shall be capable of characterizing the following image artifacts:		X	
3.3.2.6.1	Striping		X	

REQ #	Requirement Summary	H/W	S/W	OPS
3.3.2.6.2	Banding		X	
3.3.2.6.3	Coherent noise		X	
3.3.2.6.4	Deleted			
3.3.2.6.5	Deleted			
3.3.2.6.6	Saturated detectors		X	
3.3.2.6.7	Dropped scan lines		X	
3.3.2.7	The LPGS shall be capable of applying compensation for the following image artifacts:		X	
3.3.2.7.1	Striping		X	
3.3.2.7.2	Banding		X	
3.3.2.7.3	Coherent noise		X	
3.3.2.7.4	Memory effect		X	
3.3.2.7.5	Scan-correlated shift		X	
3.3.2.7.6	Inoperable detectors		X	
3.3.2.7.7	Saturated detectors		X	
3.3.2.7.8	Dropped scan lines		X	
3.3.2.8	The LPGS shall be capable of applying compensation for gain changes within a requested L1 scene or subinterval as identified in the Level 0R metadata.		X	
3.3.2.9	The LPGS shall be capable of producing L1R data from L0R data for both the ascending and descending portions of the Landsat 7 orbit.		X	
3.3.2.10	The LPGS shall be able to produce L1R digital images for any combination of the eight spectral channels.		X	
3.3.2.11	The LPGS shall assemble and append to the L1R digital images all of the applicable metadata, quality and accounting data gathered in the construction of the L1R digital image. The complete L1R digital image package contains the following data elements as a minimum:		X	
3.3.2.11.1	Level 1R digital image (all requested bands))		X	
3.3.2.11.2	L1 metadata file		X	
3.3.2.11.3	Quality and accounting file		X	
3.3.3	The LPGS shall be able to extract and process Landsat 7 ETM+ Earth image data from the L1R Earth image data files to produce systematically corrected L1G digital images.		X	
3.3.3.1	The LPGS shall have the capability to resample L1R digital images and apply the following map projections:		X	
3.3.3.1.1	Space Oblique Mercator		X	
3.3.3.1.2	Universal Transverse Mercator (UTM)		X	
3.3.3.1.3	Lambert conformal conic		X	
3.3.3.1.4	Transverse Mercator		X	
3.3.3.1.5	Oblique Mercator		X	
3.3.3.1.6	Polyconic		X	
3.3.3.1.7	Polar stereographic		X	

REQ #	Requirement Summary	H/W	S/W	OPS
3.3.3.2	The LPGS shall support the following compensation resampling methods:			
3.3.3.2.1	Nearest neighbor		X	
3.3.3.2.2	Cubic convolution		X	
3.3.3.2.3	Modulation Transfer Function (MTF)		X	
3.3.3.3	The LPGS shall have the capability to produce L1G digital images with the following grid cell characteristics:			
3.3.3.3.1	Grid cell size is variable from 15M to 60M in 0.001M increments		X	
3.3.3.3.2	Grid cell size is independently variable between spectral bands		X	
3.3.3.4	The LPGS shall produce L1G digital images that are spatially continuous between contiguous partial subintervals or WRS scenes.		X	
3.3.3.5	The LPGS shall have the capability to generate L1G digital images oriented by the following:			
3.3.3.5.1	Nominal Path		X	
3.3.3.5.2	North Up		X	
3.3.3.6	The LPGS shall be capable of producing L1G data from L0R data for both the ascending and descending portions of the Landsat 7 orbit.		X	
3.3.3.7	The LPGS shall be able to produce L1G digital images for any combination of the eight spectral channels.		X	
3.3.3.8	The LPGS shall assemble and append to the L1G digital images all of the applicable metadata, quality and accounting data gathered in the construction of the L1G digital image. The complete L1G digital image package contains the following data elements as a minimum:		X	
3.3.3.8.1	Level 1G digital image (all requested bands)		X	
3.3.3.8.2	L1 metadata file		X	
3.3.3.8.3	Quality and accounting file		X	
3.3.4	Generate L1 metadata file.			
3.3.4.1	The LPGS shall generate ancillary L1R digital image data that describes the contents, processing parameters, and quality indicators of the L1R digital image.		X	X
3.3.4.2	The LPGS shall generate ancillary L1G digital image that describes the contents, processing parameters, and quality indicators of the L1G digital image.		X	X
3.3.4.3	The LPGS shall generate and append processing summary indicators specifying the algorithms applied to the Level 1 digital images.		X	
3.3.5	Assess L1 product quality.			
3.3.5.1	The LPGS shall support automatic assessment of L1 digital image quality.		X	
3.3.5.2	The LPGS shall be able to optionally display any single band of the L1R digital image for visual quality assessment.		X	X
3.3.5.3	The LPGS shall be able to optionally display any single band of the L1G digital image for visual quality assessment.		X	X

REQ #	Requirement Summary	H/W	S/W	OPS
3.3.5.4	The LPGS shall be able to optionally print a color hardcopy of the display of any band(s) of the L1R digital image for visual quality assessment.		X	X
3.3.5.5	The LPGS shall be able to optionally print a color hardcopy of the display of any band(s) of the L1G digital image for visual quality assessment.		X	X
3.3.6	Transfer L1 file(s).			
3.3.6.1	The LPGS shall be able to output L1 digital images in the following formats:			
3.3.6.1.1	HDF-EOS (L1R and L1G)		X	
3.3.6.1.2	EOSAT FAST-Format (L1G only)		X	
3.3.6.1.3	GeoTIFF (L1G only)		X	
3.3.6.2	The LPGS shall transfer L1 files to ECS per the ECS to LPGS ICD.		X	
3.3.6.3	The LPGS shall provide the capability to display LPGS level 1 file transfer summary upon operator request.		X	X
3.3.6.4	The LPGS shall be able to detect files that have been successfully transferred.		X	
3.3.6.5	The LPGS shall be able to mark successfully transferred files as candidates for deletion from LPGS temporary storage.		X	
3.3.7	Data storage			
3.3.7.1	The LPGS shall be able to provide temporary online storage for the equivalent of 3 days of completed products.	X	X	
3.3.7.2	The LPGS shall be able retransmit files located in temporary storage.	X	X	
3.3.7.3	The LPGS shall be able to store Level 1 processing information on line for 90 days.		X	
3.3.7.4	The LPGS shall be able to transfer Level 1 processing information to offline storage after 90 days.		X	X
3.3.7.5	The LPGS shall be able to recover, display, and print Level 1 processing information located on offline storage for the life of the mission.	X	X	X
3.3.7.6	The LPGS shall be able to provide temporary online storage for up to 25 L0R scene equivalents and associated input files.	X	X	
3.3.8	Control LPGS operations.			
3.3.8.1	LPGS shall allow the operator to select thresholds for statistics and errors reported by the LPGS.		X	X
3.3.8.2	The LPGS shall automatically generate messages and alarms to alert the operator of LPGS results and errors exceeding operator selected thresholds.		X	X
3.3.8.3	The LPGS shall generate intermediate processing summaries on a periodic basis according to operator specification.		X	X
3.3.8.4	The LPGS shall provide an option to display L1 digital image quality status and statistics at operator request.		X	X
3.3.8.5	The LPGS shall provide an option to print L1 digital image quality status and statistics at operator request.	X	X	X
3.3.8.6	The LPGS shall provide the capability to manually override the LPGS automated processing functions.		X	X

REQ #	Requirement Summary	H/W	S/W	OPS
3.3.8.7	The LPGS shall provide the manual capability to cancel Level 1 processing prior to completion of digital image generation.		X	X
3.3.8.8	The LPGS shall be able to display and print trouble tickets received from ECS.	X	X	X
4	LPGS Performance Requirements			
4.1	Performance Requirements.			
4.1.1	The LPGS shall be capable of processing a volume of data equivalent to 28 (accounts for 10 percent of LPGS internal reprocessing) standard L0R WRS scenes to Level 1 digital images each day.		X	
4.1.2	The LPGS shall contribute no greater than .7 percent uncertainty to absolute radiometric accuracy during the generation of L1R and 1G digital images.		X	
4.1.3	The LPGS shall contribute circular errors no greater than 1.8 m, 1 sigma, in the production of systematically corrected L1G digital images.		X	
4.1.4	The LPGS shall provide at least 110 percent of the processing throughput capability required to satisfy the worst case processor loading.	X	X	
4.1.5	The LPGS shall provide at least 125 percent of the random access memory capacity required to satisfy the worst case memory loading.		X	
4.1.6	The LPGS shall provide at least 125 percent of the peripheral storage capacity required to satisfy the worst case peripheral storage loading.	X		
4.1.7	Deleted			
4.1.8	The LPGS shall produce Level 1G products that are accurate to within 250 meters cross track and 250 meters along track using geometric calibration information generated by IAS and contained in the associated calibration parameter file,		X	
4.2	External interface performance requirements.			
4.2.1	The LPGS shall be able to ingest from ECS a data volume equivalent to 3 WRS scenes worth of standard L0R data for each Level 1 digital image request.	X	X	
4.2.2	The LPGS shall have the capability to support the transfer to ECS of the equivalent of a minimum of 25 WRS sized Level 1 digital images per day.	X	X	
4.2.3	The LPGS-ECS interface shall provide the capability to transfer to the ECS at least 33 GB of Level 1 output files per day.	X	X	
4.3	Reliability, maintainability, and availability.			
4.3.1	The LPGS shall provide an operational availability of .96 (TBR).	X		
4.3.2	The LPGS shall support a mean time to restore (MTTR) capability of 4 hours (TBR).	X		
4.4	Security			
4.3.1	The LPGS shall provide system, network, and operations security according to the ESDIS security policy (Applicable Document 8) and the NASA AIS Handbook (Applicable Document 9).	X	X	X

Appendix C. System Design Analysis and Trade Studies

C.1 Throughput and Sizing Analysis

The storage sizing for the LPGS was determined using a workflow model that traced the flow of data through each stage of processing. The following steps were identified in the model:

- Data ingest
- Data processing (L1R or L1G)
- Visual QA
- Transfer to ECS

For the purposes of sizing, it was assumed that requests would be worked off in a sequential manner over the entire 24-hour day, that one request would be in each step of processing at a time, and that the visual QA step would only occur on the prime shift. Based on these assumptions, the spreadsheet in Table C-1 was prepared.

This table shows for each shift the number of L0R scenes requested (assumed to be one-third of the total expected requests). L0R scenes are used as the basic unit of processing because the throughput requirements are stated in number of L0R scenes/day. It is assumed that each scene request is to be worked off during the same shift, resulting in no backlog of requests from the ECS. As each scene is requested, it is processed, resulting in no backlog of processing. However, since the output is inspected only during prime shifts, no scenes are assessed during the hours from 16:00 - 08:00. Therefore, a backlog is accumulated every day equivalent to 17 L0R scenes. Because it is assumed that the backlog is to be worked off every day, the maximum backlog will not grow. The requirement to provide the equivalent of 25 L0R scenes/day to the ECS is evenly divided across all three shifts. This division results in a large number of scenes being prepared for transmission during the prime shift and then worked off over the next three shifts. This procedure results in a maximum backlog of 17 scenes waiting for transmission to the ECS.

Table C-1. Backlog Analysis

Shift	Scenes Req'd	Cum. Scenes Req'd	Scenes From DAAC	Cum. Scenes From DAAC	Request Backlog	Scenes Processed	Cum. Processed	Processing Backlog	Scenes Inspected	Cum. Inspected	Inspection Backlog	Scenes to DAAC	Cum. to DAAC	DAAC Backlog
00:00-08:00	8	8	8	8	0	8	8	0	0	0	8		0	0
08:00-16:00	8	16	8	16	0	8	16	0	16	16	0	5	5	11
16:00-24:00	9	25	9	25	0	9	25	0	0	16	9	5	10	6
00:00-08:00	8	33	8	33	0	8	33	0	0	16	17	6	16	0
08:00-16:00	8	41	8	41	0	8	41	0	25	41	0	8	24	17
16:00-24:00	9	50	9	50	0	9	50	0	0	41	9	8	32	9
00:00-08:00	8	58	8	58	0	8	58	0	0	41	17	9	41	0
08:00-16:00	8	66	8	66	0	8	66	0	25	66	0	8	49	17
16:00-24:00	9	75	9	75	0	9	75	0	0	66	9	8	57	9
00:00-08:00	8	83	8	83	0	8	83	0	0	66	17	9	66	0
08:00-16:00	8	91	8	91	0	8	91	0	25	91	0	8	74	17
16:00-24:00	9	100	9	100	0	9	100	0	0	91	9	8	82	9
00:00-08:00	8	108	8	108	0	8	108	0	0	91	17	9	91	0
08:00-16:00	8	116	8	116	0	8	116	0	25	116	0	8	99	17
16:00-24:00	9	125	9	125	0	9	125	0	0	116	9	8	107	9
00:00-08:00	8	133	8	133	0	8	133	0	0	116	17	9	116	0
08:00-16:00	8	141	8	141	0	8	141	0	25	141	0	8	124	17
16:00-24:00	9	150	9	150	0	9	150	0	0	141	9	8	132	9
00:00-08:00	8	158	8	158	0	8	158	0	0	141	17	9	141	0
08:00-16:00	8	166	8	166	0	8	166	0	25	166	0	8	149	17
16:00-24:00	9	175	9	175	0	9	175	0	0	166	9	8	157	9
00:00-08:00	8	183	8	183	0	8	183	0	0	166	17	9	166	0
08:00-16:00	8	191	8	191	0	8	191	0	25	191	0	8	174	17
16:00-24:00	9	200	9	200	0	9	200	0	0	191	9	8	182	9

Table C-2 shows the equivalent data for one L0R scene for each type of data. The columns are defined as follows:

- L0R—A single scene of L0R data
- L1R—Processed data to L1R for a single L0R scene
- L1G—Processed data to L1G for a single L0R scene
-

Table C-2. Equivalent Data Storage for One L0R Scene

Data Type	L0R	L1R	L1G
GB/scene	0.5	1.4	1.4

Table C-3 shows the storage requirements on the disk arrays. All data (L0R, CAL, L1G, and L1R) will be stored on the disk arrays. They are sized to hold 3 L0R scenes, 3 days of L1 products, and 1 day of reprocessed data, with a 25 percent margin.

Table C-3. Storage Requirements by Location

Data	Total
L0R products	1.9
3 days of L1 products (includes CAL data)	131.3
1 day of reprocessed data	5.3

Abbreviations and Acronyms

AAS	anomaly analysis subsystem
API	applications programming interface
cNMOS	consolidated Network and Mission Operations Support
COTS	commercial off-the-shelf
CPU	central processing unit
DAAC	Distributed Active Archive Center
DAT	digital audio tape
DBMS	Database Management System
DD	data dictionary
DDE	data dictionary entry
DFD	data flow diagram
DHF	Data Handling Facility
DMS	data management subsystem
ECS	EOSDIS Core System
EDC	EROS Data Center
EGS	EOS Ground System
EOS	Earth Observing System
EOSAT	Earth Observation Satellite Company
EOSDIS	EOS Data and Information System
EROS	Earth Resources Observing System
ESDIS	Earth Science Data and Information System
ETM+	Enhanced Thematic Mapper Plus
F&PRS	functional and performance requirements specification
FAST	an output format for L1 digital images
FDDI	fiber distributed data interface
FIFO	first in, first out
GB	gigabytes

GDS	ground data system
GeoTIFF	an output format for L1 digital images
GPS	geometric processing subsystem
GSFC	Goddard Space Flight Center
GUI	graphical user interface
HDF	hierarchical data format
HWC	hardware component
HWCI	hardware configuration item
I/O	input/output
IAS	Image Assessment System
IC	internal calibrator
ICD	interface control document
IDD	interface data descriptions
IDL	Interactive Development Language
IGS	international ground station
ISO	International Standards Organization
L0R	Level 0R
L1	Level 1
L1G	Level 1G
L1R	Level 1R
LGN	Landsat ground network
LGS	Landsat 7 ground station
LPGS	Level 1 Product Generation System
LPS	Landsat 7 Processing System
M	meter
MB	megabytes
Mbps	megabytes per second
mm	millimeter
MMO	Mission Management Office

MO&DSD	Mission Operations and Data Systems Directorate
MOC	Mission Operations Center
MSCD	mirror scan correction data
MTF	modulation transfer function
MTTR	mean time to restore
NASA	National Aeronautics and Space Administration
NCSA	National Center for Supercomputing Applications
NFS	Network File System
NOAA	National Oceanic and Atmospheric Administration
PC	personal computer
PCD	payload correction data
PCMB	Project Configuration Management Board
PCS	Process Control Subsystem
QA	quality assessment
QAS	quality assessment subsystem
RAID	redundant array of inexpensive devices
RMA	reliability, maintainability, and availability
RPC	remote procedure call
RPS	radiometric processing subsystem
RSI	Research Systems, Inc.
RTM	Requirements and Traceability Management (tool)
SDR	system design review
SDS	system design specification
SGI	Silicon Graphics, Inc.
SNR	signal-to-noise ratio
SRR	system requirements review
SSR	solid-state recorder
SWCI	software configuration item
SQL	Structured Query Language

TBD	to be determined
TBR	to be resolved
TBS	to be supplied
TIFF	tagged image file format
USGS	United States Geological Survey
WRS	Worldwide Reference System

Glossary

0R. The stage in the processing before radiometric or geometric correction of an image and after the pixels have been placed in detector spatial order.

L0R product. Products distributed by the ECS to include all bands, 0R image data, metadata, internal calibrator data, calibration parameter file, the browse image, the PCD, and the MSCD.

L1R. The stage in the processing after radiometric correction has been applied to an image and geometric coefficients are appended but not applied.

L1G. The final stage in the processing after radiometric and geometric corrections have been applied to the image data.

Ancillary data. Spacecraft attitude and ephemeris, radiometric correction coefficients, geometric processing parameters, and image quality statistics.

Archive. Offline storage of data, software, and documentation.

Calibration activities. Recalculating of the radiometric correction coefficients or geometric processing parameters.

Data storage. Online storage of data accessible to the various functions within the LPGS.

ETM+ equivalent scene:

L0R image data (6320+225) x 5984 x 6 + ((12640 +450) x 11968) +

((3160 + 113) x 2992x2) = 0.41 GB

Level 1G, nonrotated, resampled to 25 meters (except Pan to 12.5 meters)

220km x 170km/(.025km/pix)^2 x 2bytes/pix x 7 bands +

220km x 170km/(.0125km/pix)^2 x 2bytes/pix = 1.3 GB

Geodetic accuracy. The accuracy relative to the geodetic reference surface, the earth ellipsoid.

Geometric accuracy. The measure of internal distortion of an image.

Geometric artifacts. Assessment of geometric artifacts (or assessment of geometric accuracy) includes visual assessment of discontinuities of linear features, scale distortion, panoramic distortion, and any other distortions.

Geometric processing parameters. Orbit parameters, instrument and alignment parameters, focal plane band locations, scan mirror profile coefficients (along scan and across scan), odd detector sample shifts, alignment matrices, Angular Displacement Sensor (ADS) calibration parameters, gyro calibration parameters, along scan focal plane detector offsets, temperature calibration coefficients, inoperable modes, resampling coefficients, MTF coefficients, and MTF compensation.

Inoperable detectors. Detectors meeting the following criteria shall be declared inoperable:

- The quantized digital number (DN) is below 50 percent of the full-scale DN value when a detector is exposed to the ETM+ minimum saturation levels.
- The quantized digital number (DN) reaches full scale while the input radiance is at or below 0.70 times the ETM+ minimum saturation levels.
- The signal-to-noise ratio (SNR) performance degrades to 50 percent or below the specified ETM+ minimum SNR values.

L0R scene product. See L0R product.

L1G digital image. Image data that have been both radiometrically and geometrically corrected.

L1R digital image. Image data that have been radiometrically corrected and to which geometric coefficients are appended but not applied.

Payload correction data (PCD). The PCD contains all data required by ground stations to geometrically correct ETM+ sensor data, and it redundantly provides the ETM+ imaging configuration. The PCD is embedded in every wideband data virtual channel data unit (VCDU) at a rate of 4 bytes of PCD per VCDU. PCD data items are

- ADS
- ADS temperature
- Gyro data
- Gyro drift data
- Attitude estimate
- Time of last SV clock update
- SV time drift characterization data
- Ephemeris
- ETM+ telemetry data
- Spacecraft ID and time code
- Multiplexer status
- PDF A/D ground reference
- Minor frame synchronization
- Major frame identification
- Spacecraft identifier

- Attitude control system mode
- ETM+ on/off times

Radiometric image artifacts. Striping, banding, scan-correlated shift, bright target recovery response (a.k.a. memory effect), coherent noise, impulse noise, detector saturation, and detector inoperability.